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VOLUME IV, 1914

RICHARD ELWOOD DODGE, *Editor*

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CONTENTS

PAGE
The Weather Element in American Climates.
Robert DeC. Ward 3
The Subdivision of North America into Natural Regions:
A Preliminary Inquiry......... Wolfgang L. G. Joerg 55
Physiographic Boundaries within the United States.
Nevin M. Fenneman 84
Titles and Abstracts of Papers, Princeton, 1913............. 135
Index.. 147

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THE WEATHER ELEMENT IN AMERICAN CLIMATES

ROBERT DE C. WARD

CONTENTS

Page
The Weather Element in the Study of Climate........................ 3
  General Relations of Weather and Climate........................ 3
  Outline of this Discussion.. 4
  Cyclonic and Anticyclonic Control of our own Weather and Climate.. 5
  Our Winter Storm Control.. 5
  Our Summer Diurnal Control.. 6
  The Combined Cyclonic and Solar Controls of our Spring and Autumn 7
Paths of Cyclones and Anticyclones in the United States................ 7
  Seasonal Grouping of Cyclonic Paths........................ 7
  Winter Cyclonic Paths.. 8
  Seasonal Variations of Storm Paths and of Weather Types.......... 10
  Paths of Anticyclones in the United States........................ 10
  Summer Cyclonic Paths.. 12
  Spring and Autumn Cyclonic Paths........................ 13
Regional and Seasonal Weather Types of the United States: General.... 14
  The Ideal as compared with the Actual Cyclone.................... 14
  Cyclonic Weather Controls in Different Sections.................. 15
Regional and Seasonal Weather Types of the Eastern United States..... 16
  Winter Weather Types of the Eastern United States............... 16
  Summer Weather Types of the Eastern United States.............. 29
  Spring Weather Types of the Eastern United States............... 30
  Autumn Weather Types of the Eastern United States.............. 31
  Curves illustrating Weather Types of the Northeastern United States 34
  Each Section has its own Weather Types........................ 37
Regional and Seasonal Weather Types of the Western United States..... 40
  Winter Weather Types of the Pacific Coast........................ 40
  Summer Weather Types of the Pacific Coast........................ 46
  Winter Weather Types of the Western Interior Province............ 51
  Summer Weather Types of the Western Interior Province.......... 52
  Winter and Summer Weather Types of the Great Plains........... 53

THE WEATHER ELEMENT IN THE STUDY OF CLIMATE.—*General Relations of Weather and Climate.*—Climate is the average of weather. Careful records of *weather,* continued for many years, give *climatic averages.*[1] In the Temperate Zones the weather is largely controlled by a succession of cyclones and anticyclones, more or less irregular in their occurrence; uncertain in their progression and duration, and differing considerably in their characteristics. Hence our weather changes are correspondingly irregular, uncertain, and diverse. The nature of these changes depends on the degree of development; the velocity of progression; the track; and other conditions of the disturbance which produces them. Of weather types there is an almost endless variety. Their detailed study belongs under Meteorology. Yet these types give our climates their distinctive characters, to a large extent determining the amount and the distribution of temperature; of precipitation; of humidity; of cloudiness. A general understanding of the nature of the cyclonic and anticyclonic control is, therefore, essential to a proper appreciation of our climate. Anyone who seriously attempts to study the climatology of the United States should have a series of weather maps in one hand, and a set of climatic charts of the country in the other. He will very soon realize that the better his understanding of the former, the more intelligent is his appreciation of the latter.

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[1] A full description of a climate is given when certain numerical data, carefully corrected, summarized, and compared by well-known methods, are tabulated in a standard form (see Hann: *Handbuch der Klimatologie,* Vol. 1, 2d ed., 1897. Translated by R. DeC. Ward).

The essence of this cyclonic control is its irregularity. It is obvious, therefore, that its effects upon all the meteorological elements must largely disappear when the conventional time units are taken as the basis for averaging climatic data. Annual, monthly, diurnal averages of the different climatic elements, when given numerically, or even when charted, are therefore often misleading. They give but a lifeless picture. They do not show how and why the conditions which they aim to represent were really brought about. It is the irregular weather changes from day to day which give most of our climates their real character, affecting our activities, crops, comfort, and health.[2] The *average* or *normal* weather of a season, a month, or even a day, is known for much of our country. It seems as if we could thus make long-range forecasts. But average weather is not what may actually happen. And it is the actual, not the normal, which we really experience.

Outline of this Discussion.—We must, therefore, try to picture to ourselves the series of weather types which, varying seasonally and regionally, make up the average sum-total of what we call our climate. The more pronounced types have a certain well-marked individuality, and a more or less systematic recurrence. As they depend so largely upon the passage of cyclones and anticyclones, we must first familiarize ourselves with the movements of these areas across the United States. This will lead us to an understanding of the more marked weather changes associated with their passage. And, finally, we shall illustrate a few of the most marked and typical weather types by means of a series of curves and simplified weather maps.

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[2] For a fuller discussion of this subject, see R. DeC. Ward: "Suggestions concerning a more Rational Treatment of Climatology," Report VIII Int. Geogr. Cong., Washington, D. C., 1905, 277-293 (contains numerous references); W. G. Reed, Jr.: "The Study of Phenomenal Climatology," Quart. Journ. Roy. Met. Soc., Vol. 36, 1910, 39-48.

Cyclonic and Anticyclonic Control of Our Own Weather and Climates.—Most of the United States is well within the belt of prevailing westerly winds, one of whose most marked characteristics is the continuous procession of cyclonic and anticyclonic disturbances which keeps marching eastward in a great spiral circuit around the North Pole. Over the Temperate Zones, as a whole, there is thus a great ring of stormy weather, oscillating poleward and equatorward as the sun moves to and fro in the course of its regular migration. Northward, across the United States, to our northern border, swings this great storm belt as the summer sun comes north of the equator. Southward it swings in winter, following the declining sun, covering the country even to the Gulf of Mexico. Scattered through the southern quadrants of our cyclonic storms, especially during the warmer months, come more local disturbances—thunderstorms and tornadoes. There is, thus, a second belt of local storms, south of the general cyclonic storm belt. This, also, swings back and forth seasonally, covering practically the whole country in summer, and being carried well into and even across the southern States in winter.

Our Winter Storm Control.—The quality of our weather types varies seasonally and geographically. These types result from a combination, more or less irregular, of periodic, diurnal elements, under the control of the sun, and of non-periodic, cyclonic and anticyclonic, elements. In winter, when practically the whole country is under the influence of the storm belt; when the sun is low and the days are short, the non-periodic control is everywhere strongest. Local conditions of heat and cold largely become subordinate to the general control by the cyclone and anticyclone, which import winds and weather from a distance. The irregular changes from clear to cloudy; from warmer to colder; from dry air to snow or rain, extend over large areas, and show but little diurnal control. Our storms are not only more widely distributed over the country in winter, but are then larger, more frequent, more violent, and move faster. Hence all our changes, of wind, temperature and weather occur oftener, are more sudden, and more emphatic during that time. Our northern, and especially our northeastern States, being most frequented by our winter storms, have the most changeable weather, the alternation between fair and stormy being repeated with considerable regularity and frequency. This cycle of cyclonic changes is run through in about two to four days. With increasing distances to the south and west, the general storm control weakens; less cloudy and stormy weather occurs, and the temperature changes are less sudden and less marked. Thus it is that our southern and especially our southwestern States have on the whole more settled, "better," winter weather, and more uniform temperature-conditions than the northern States. New Mexico, Arizona, western Texas, southern California, for example, are so far removed from our most frequented storm belts, and their own cyclones are on the whole so weak, that they enjoy an abundance of sunshine, have little precipitation, and that mostly in brief showers. Our Gulf States, and especially Texas, are, however, exposed to occasional invasions of severe cold from the north, when winter cyclones, traveling well to the south, are followed by cold waves. These cold waves, if they come early in the winter, or last long, may result in great damage to crops.

Our Summer Diurnal Control.—From the irregular storm control which is so powerful in winter, to the dominant solar control of summer is a characteristic change which, year after year, is accomplished with the orderly sequence of the seasons. In summer, when the general storm belt swings to the north, followed, on its southern side, by the thundershower belt, the cyclonic element in our weather changes is weakest. The cyclone, with its irregular control over all our weather elements, gives way to the sun. In place of the turbulent atmospheric circulation of the colder months we have the gentler movements of the warmer. The temperature-distribution the country over is remarkably uniform. The prevailing temperatures are high; the variations small; the gradients weak. The dominant weather types are associated with the regular changes from day to night. Periodic, diurnal phenomena replace non-periodic, cyclonic phenomena. Cumulus clouds, especially noticeable on days which follow rainfalls; diurnal variations in temperature and in wind velocity; afternoon thunderstorms, recurring in spells with considerable regularity, characterize the warmer months over most of the country and present an analogy with tropical conditions. Cyclonic and anticyclonic spells of hotter or cooler, rainy or dry weather, with varying winds differing in the temperatures and moistures which they bring, serve to break the regularity of the simple, diurnal, sun-controlled types. Summer is the season of weak, poorly developed, slow-moving storms, mostly following our northern borders; of few nimbus clouds; of local rather than widespread general rains; of relatively small changes of temperature; of light and variable winds. The squall winds of our passing thunderstorms, and the violent inrushing blasts of our tornadoes, are local and temporary interruptions of the generally calm and peaceful regime of our summer weather. Our southern and western States, being well removed from the storm belt, have a succession of typical "settled," diurnal changes, day after day, with few general rains, but share with most of the country the local disturbances characteristic of the thunderstorm belt. The northern tier of States, east of the Rocky Mountains, being at the southern margin of the summer storm belt, experiences the irregular changes which result from the eastward progression of summer cyclones. These changes are, however, far less marked than in winter. They are often little more than a series of warmer and cooler spells, often repeated fairly systematically in a period of roughly about four to eight days; with thunderstorms and long periods of uniform temperatures interspersed.

The Combined Cyclonic and Solar Control of Our Spring and Autumn.—Spring and autumn are transition seasons, and have their own transitional weather types. In spring, the growing diurnal element is marked by the increasing importance of local controls; by the appearance of convectional phenomena such as cumulus clouds and "April showers;" by the struggle between cyclonic and solar controls of temperature, now one, now the other, being paramount, but the latter gaining, the former losing. The storm control becomes increasingly uncertain and weaker; the storm movements are slower and more erratic. Irregularly, spasmodically, is the transition from winter to summer accomplished. Wintry spells are interpolated between summer spells. But the latter become more marked, last longer, advance further northward, as the former come less frequently, are less emphatic, and gradually withdraw to higher latitudes. March is usually a turbulent and unpleasant month in northeastern sections, with quick alternations of wintry conditions and of types indicative of approaching summer.[3]

With the passing of summer into autumn the sun's rays become more and more oblique, and weaken; the temperature falls; the days grow shorter; the control of our weather passes gradually but irregularly from the sun back again to the cyclone; from the mildness of summer to the turbulence of winter. The decrease in diurnal phenomena, such as local thunderstorms, is an autumnal characteristic. As autumn draws to its close, the irregular cyclonic regime of winter is once more established. It is in the north and east, close to the most frequented storm belts, that the cyclonic control continues longest in spring. So it is also in these same districts that the storm control first makes itself felt in autumn.

PATHS OF CYCLONES AND ANTICYCLONES IN THE UNITED STATES.—*Seasonal Grouping of Cyclonic Paths.*—We may now turn to a somewhat closer examination of the regions over which our cyclones move most frequently. It is a mistake to picture to ourselves any rigid system of clearly-defined storm "tracks." There are, rather, certain broad belts or districts over which our cyclones travel more frequently than elsewhere. For our present climatological purpose it is best to generalize, showing these most frequented regions as broad belts, and realizing that there is no very close and definite relation of our cyclones to these paths. For the sake of simplicity we divide the year into three parts, as suggested by Professor F. H. Bigelow, whose careful study of our storm tracks is our best source of information on this subject.[4] Each of these divisions has its own more or less distinctive meteorological characteristics, cyclonic and anticyclonic belts, and weather types. December, January, February and March are winter; June, July, August and September are summer; April and May, and October and November, are spring and autumn, respectively.

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[3] Professor O. L. Fassig has shown that the types of weather, storm paths, and amount and character of precipitation in March, depend upon the relations and development of the continental, the Atlantic and the Pacific anticyclones ("Types of March Weather in the United States," *Amer. Journ. Sci.*, 4th Ser. Vol. 8, No. 47, Nov., 1899, 319-340).

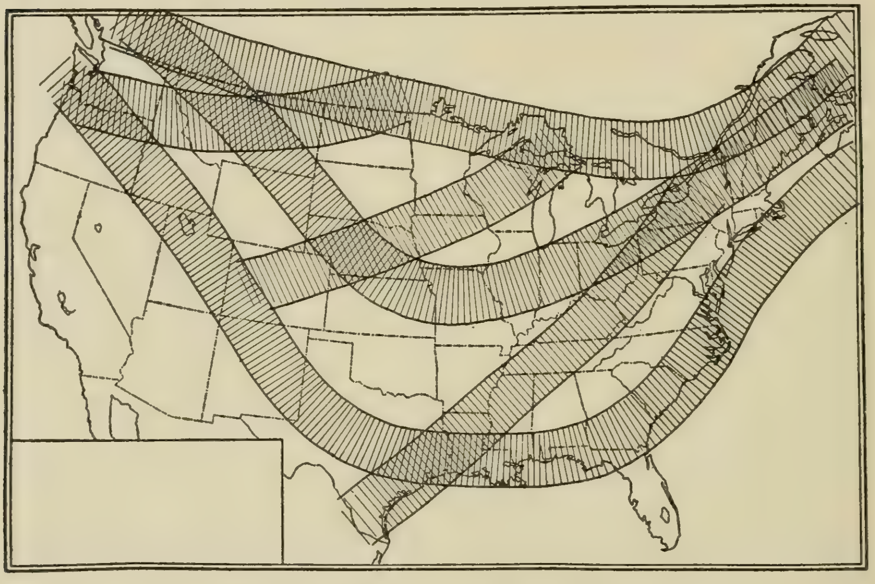

FIG. 1.—Generalized Winter Storm Paths.

Winter Cyclonic Paths.—Most of our winter cyclones appear first on our weather maps in the region north of Montana ("Alberta Type"), and are probably offshoots from the great cyclone over the

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[4] F. H. Bigelow, "Storms, Storm Tracks and Weather Forecasting," U. S. Weather Bureau, Bulletin No. 20, Washington, D. C., 1897. A. J. Henry, "Climatology of the United States," U. S. Weather Bureau, Bulletin Q, Washington, D. C., 1906. Professor Henry lays much emphasis upon cyclonic and anticyclonic controls of American weather. Professor Bigelow's and Professor Henry's discussion has been followed in the description of storm paths, but the charts are the present writer's.

North Pacific Ocean. Thence they travel southeast and east along a path which is known as the "Northern Circuit," across the Great Lakes and down the St. Lawrence Valley to the Atlantic Ocean. The time usually occupied for this journey is between three and four days.[5] Some of these storms loop southward over the eastern Rocky Mountain slope to Iowa and Missouri, cross the Mississippi Valley, and then move northeast to the northern circuit, occupying about three days to the Lower Lakes. Towards spring, occasional storms of this type are deflected south to the Gulf, under the influence of well-marked anticyclones moving southeast from the region north of Montana. When a new storm comes in from the northwest there is frequently an anticyclone over the southern or central States, moving east slowly, and a retreating cyclone in the northeast.

From the northern Pacific coast comes a considerable procession of storms ("North Pacific Type") which move eastward on the northern circuit. Some of this group, especially in the late winter, make a wide swing southeastward (roughly with eastern North Dakota as a centre and with a radius of 1,200 miles, more or less, in length) across the Basin Region, New Mexico and western Texas, and then northeast to the Gulf of St. Lawrence. This southern storm belt is known as the "Southern Circuit." The cyclones of the North Pacific type make their southward loop under the control of high pressures over the northern central and the Missouri valleys. For the transcontinental journey, from the Pacific to the Atlantic, about four days are needed, this being, it will be observed, a little more rapid than the rate of travel of a through express train making the same trip. The long swing over the southern circuit is usually made at such high velocity that the time occupied on the journey is about the same as when the northern circuit is followed. Other storms of the North Pacific type make a more moderate loop to the southeastward over the Plateau region, crossing the Rocky Mountains between latitudes 35° and 45°, and then moving northeast across the Lakes.

From in or near Colorado ("Colorado Type") comes a group of storms which usually joins the northern circuit in the Lake region;[6] or may travel eastward on the southern circuit.

From Texas and the Gulf of Mexico another group moves northeast, west of the Appalachians, across the central valleys to the Lower Lakes, and thence eastward down the St. Lawrence Valley; or, taking the outside track east of the Appalachians, travels along the Atlantic coast to the Maritime Provinces as coast storms. The journey to

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[5] To eastern Dakota, 1 day; Lake Superior, 2 days; middle St. Lawrence Valley, 3 days.

[6] One day to Illinois; 2 days to northern New York; 3 days to the Gulf of St. Lawrence.

New England is accomplished in about two days, but an anticyclone on the Gulf of St. Lawrence may delay the progress of the storm a day or two. As pointed out by Professor F. H. Bigelow, the Texas (" Texas " or " Southwestern Type ") storms have much in common with the Colorado type, just noted, but the whole pressure system of the former is about a day's journey farther along. Storms from the Gulf of Mexico (" Gulf Type ") start even farther east on the southern circuit than the Texas type. And some " coast storms " appear on the southern Atlantic coast and move northeast.

The larger facts of our winter storm movements stand out clearly: the two main circuits, northern and southern; the " spur tracks " leading from one to the other; the marked southward looping; the convergence of all the storm paths toward the northeast. This northeastern section must, obviously, have the most changeable weather in the United States.

Seasonal Variations of Storm Paths and of Weather Types.—These storm paths themselves, and the number of storms which follow given paths, are not fixed. They vary somewhat from year to year, and probably also in longer periods. Such variations control the character of our seasonal weather types. The types normally characteristic of the season may thus be more or less completely reversed, or interrupted. If we depend solely upon the usual monthly averages of temperature and rainfall, these seasonal variations in weather types are often obscured. It is only by reference to the daily weather maps that the actual conditions can be understood. If more winter storms follow the southern circuit there is likely to be unusually cold weather east of the Rocky Mountains. If more winter storms follow the northern paths, there are likely to be more southerly winds, higher temperatures, and fewer and briefer interruptions by cold northwesterly winds over the southern States. The controls of such seasonal variations in storms and storm tracks are to be sought in the development and location of the larger, permanent, areas of high and low pressure over the continent and also over the adjacent oceans.

Paths of Anticyclones in the United States.—The movements of our anticyclones are closely associated with the movements of our cyclones, and the quality of our weather largely depends upon the particular combinations, in position, development, and character, of these high and low pressure areas. The main anticyclonic paths are strikingly similar to those of the cyclones, the general tendency of the former being to run more southerly.

There are two places of origin for our anticyclones, and two main paths, as shown in Fig. 2.[7] They come either (1) from the northwest, outside of our own territory in western Canada, entering the United States near the 115th meridian, or (2) from the Pacific Ocean west of California. The latter are probably offshoots from the permanent high pressure area of the North Pacific. The first group move (a) somewhat southerly and then easterly along our northern boundary, crossing the Lake region to the Atlantic coast or the Gulf of St. Lawrence, or (b) southeast from their place of origin, along the Rocky Mountain slope to the Gulf States, thence east to the southern Atlantic coast near Florida, perhaps continuing northeast to the Gulf of St. Lawrence.

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[7] The paths here shown are those given by Professor Bigelow.

The second group, from the California coast, also generally follow one of two broad paths. They travel either (a) northeast along the Pacific slope to Washington and Oregon, and then along the northern circuit to the Atlantic coast, or (b) southeast from California to the southern Atlantic coast, crossing the mountains near Great Salt Lake. Anticyclones of this second group are limited to the warmer months, between April and September. From the northern to the southern circuit there are "spur tracks," as along the eastern Rocky Mountain slope, and across the northern plateau from Washington to Montana. Some of the relations of these anticyclonic paths to weather types in different parts of the country will be considered later. In general, the winter anticyclones are well marked, and, although stationary for long periods over the Plateau and Basin region, as a whole show fairly well defined movements along the usual paths. In summer, on the

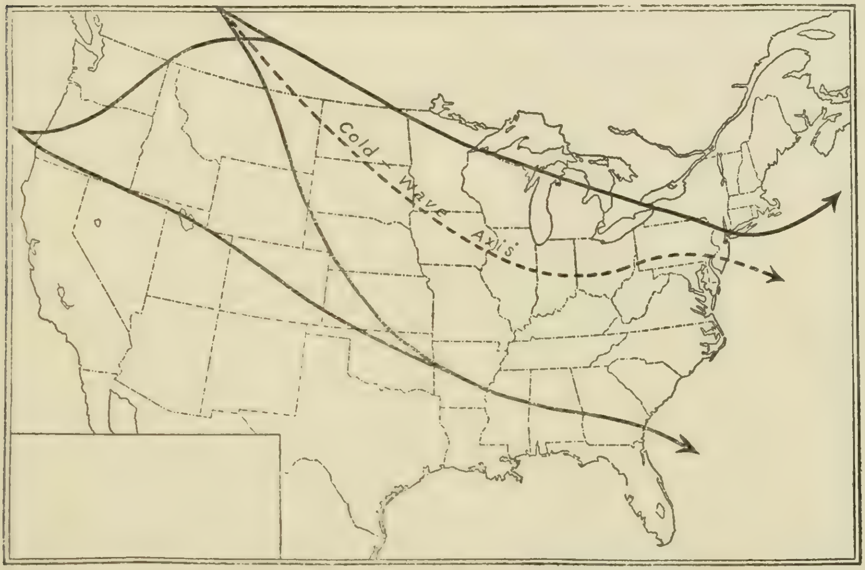

FIG. 2.—Generalized Anticyclonic Paths (after Bigelow).

other hand, the high pressure areas are generally much less emphatic, and have a much greater tendency to wander about aimlessly.

Summer Cyclonic Paths.—A comparison of Fig. 3, showing the generalized summer storm paths, with Fig. 1, showing the winter storm paths, will serve to emphasize the striking difference between these two seasons in the matter of cyclonic control of weather. In summer, our prevailing weather conditions are best described as "flat" and "stagnant." Our cyclones—generally mild and gentle in character and not bringing widespread rains—travel on the northern circuit, with "feeders" from the middle-eastern slope of the Rocky Mountains, and an occasional Atlantic coast storm or West Indian hurricane. Storms rarely come directly from the northern Pacific coast. In midsummer, this group even disappears entirely. There is much less southward looping than in winter. So weak and poorly developed are many of our summer cyclones that, after wandering about indefinitely for a time, they often fade away before reaching the Gulf of St. Lawrence. The highs, also, are weaker and less emphatic than in winter.

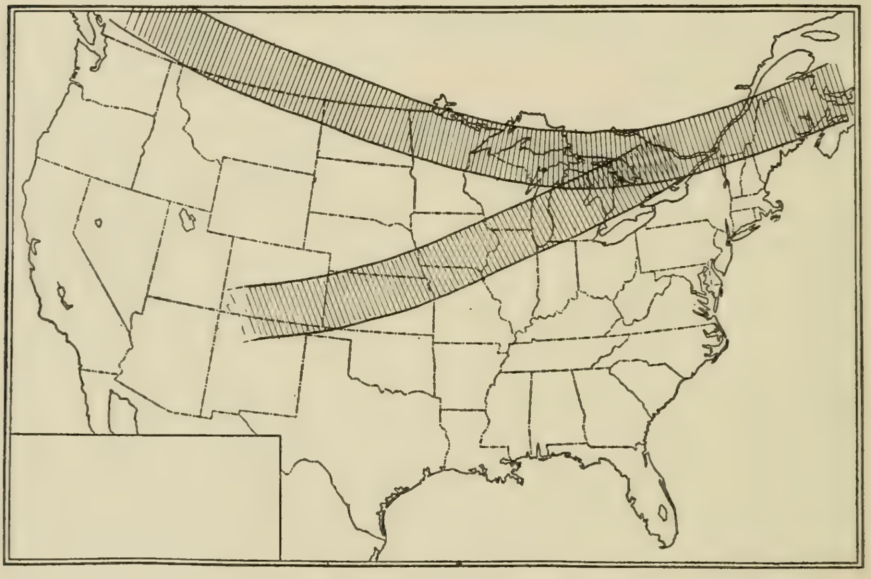

FIG. 3.—Generalized Summer Storm Paths.

A comparatively rare, but important type of late summer storms includes the West Indian Hurricanes. These, moving in from the east or northeast at about Lat. 25° N, recurve toward the north, and usually follow the Atlantic coast to Nova Scotia. Sometimes, as in the case of the Galveston storm of September 8, 1900, they cross the

Gulf of Mexico to the west, and then travel northward across the central valleys. The usual path of these hurricanes is shown on Fig. 4, for the months of October and November, rather than on Fig. 3, because they are too infrequent in summer to justify their inclusion in so highly generalized a chart as Fig. 3. West Indian hurricanes are not regular or marked weather controllers in either summer or autumn.

Spring and Autumn Cyclonic Paths.—The storm paths for spring and autumn may conveniently be generalized together (Fig. 4). In both seasons, our cyclones are more or less erratic, but their southward looping is seen to be less marked than in winter and more marked than in summer. The velocity of travel in these transition seasons is less than in winter. Thus, at the end of April, storms of the Alberta type, on the northern circuit, take about one extra day for their eastward journey. In April, the North Pacific type storms, when deflected far to the south, make their journey to the Gulf of St. Lawrence in about five days. This is also the time taken by those of the Colorado type. Those from Texas also take an extra day (3 days) to reach the Gulf of St. Lawrence. In spring, a number of storms which are important for the eastern United States come from the middle-eastern Rocky Mountain slope, and move northeast across the Lake region and New England. One of the characteristics of autumn is the increase in the number of anticyclones from the region north of Montana and from still further west, and the occasional

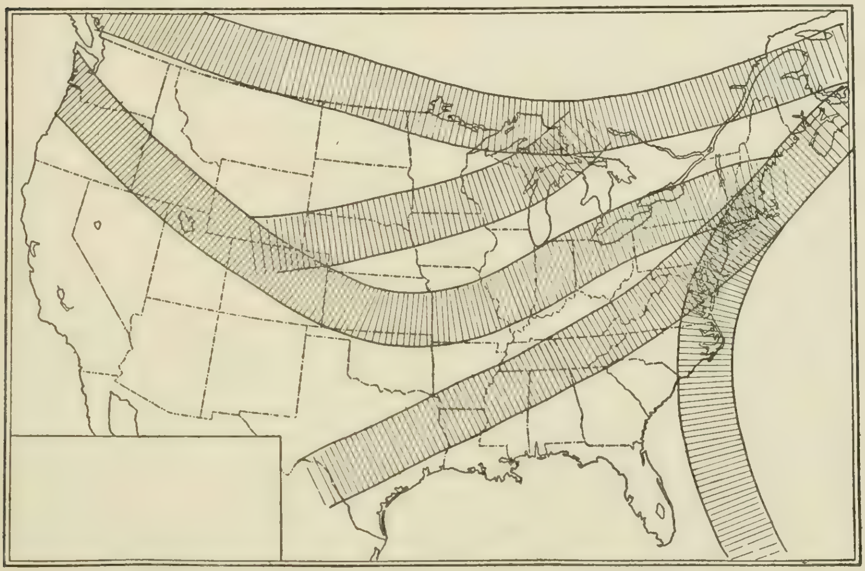

FIG. 4.—Generalized Spring and Autumn Storm Paths.

passage of a tropical cyclone (West Indian hurricane) along the Atlantic coast, referred to in the previous paragraph.

REGIONAL AND SEASONAL WEATHER TYPES OF THE UNITED STATES: GENERAL.—*The Ideal as compared with the Actual Cyclone.*—A diagram of the 'average distribution of the weather elements around an ordinary cyclone,' such as is printed in many meteorological text-books, is misleading. The impression made thereby is that cyclones are always like the ideal one shown in the figure. It seems as if, when a cyclone moves across country, we should imagine this ideal diagram, presumably representing the actual weather conditions in that cyclone, to be drawn eastward across a map of the United States as if it were hung on a wire and pulled by a string. This is a very misleading conception. Cyclones differ greatly from one another. Each has its own peculiar characteristics, although they all conform to the same general laws. They differ in character with the seasons. They differ with the topography and general physical conditions of the region over which they move. They differ with the varying conditions of other accompanying, and with the effects of preceding, cyclones and anticyclones. Therefore, if we are to gain an accurate and vivid impression of the weather conditions which make up and control our climates we must next examine our weather types as they vary with the season and with the district.

In making such a study it naturally suggests itself that we follow one "typical" cyclone, or anticyclone, across country, noting its control over the weather in the successive sections which it passes on its eastward march. This is not practicable. For it is difficult, if not impossible, to find cases of "typical" cyclones, following "typical" paths with average velocities, and controlling the regional weather conditions in a "typical" way all across the United States. Individual type weather maps are far less satisfactory for the purpose of such an investigation than broadly generalized, composite, types of *conditions of the same general character.* The exact weather distribution of an individual map, or of a series of individual maps, will never occur again. Moreover, maps which seem to be identical do not necessarily produce identical results. Hence, in the illustrations of regional weather types which follow (Figs. 5-24), no attempt has been made to reproduce any actual weather maps, or even any composites compiled by tracing from any number of selected maps. The effort has rather been to show the general conditions of pressure, temperature, winds and weather commonly associated with cyclones of different groups. These charts have been compiled after a study of some hundreds of weather maps, and are, in fact, highly generalized composites, drawn free-hand. It is, manifestly, impossible within the limits of this discussion to attempt the illustration of any considerable number of weather types. The composites given below concern a few of the more common cyclonic conditions, chiefly in the eastern United States and in winter.

Cyclonic Weather Controls in Different Sections.—In general, we may naturally expect that when a cyclone is central in the Great Basin, for example, or on the eastern Rocky Mountain slope, or in New Mexico, the amount and distribution of its precipitation will be different from that when the same storm, or a similar one, is located east of the Rocky Mountains, let us say, or over the central valleys. In the first case, the enclosing mountain ranges to a large extent shut out the influence of the surrounding water bodies, and may readily be supposed to interfere with the systematic development of the cyclonic wind system; the inflowing winds in the southeast quadrant may be dry and non-rainy, or perhaps give only local showers. In the second case, coming from the Gulf of Mexico, winds in the southerly quadrant may cause widespread general rains. Again, when a cyclone approaches the Atlantic coast, a still further difference may be observed. Then the winds throughout the eastern quadrants may be coming across water surfaces (Great Lakes, Atlantic, Gulf of Mexico), there is a greater supply of moisture, and the rainfall area may be to the northeast as well as to the southeast of the centre. Thus, there is a natural difference as regards precipitation between cyclones in the western interior and in the eastern United States. In the latter, the heavy rainfalls are usually found southeast of, and at a distance of 300 miles or so from, the storm centre. In the eastern United States, from the Mississippi and Missouri valleys to the Atlantic coast, rain usually begins during the colder months with a falling barometer. In the warmer season, however, except in connection with general storms, the precipitation, in showers and thunderstorms, usually comes with the turn from falling to rising pressure. On the Pacific coast, rain generally commences with falling pressure. But during most of the time over the Plains, and in the Rocky Mountain and Plateau districts, rain does not begin until the cyclonic centre has passed by to the south or east, and the pressure is beginning to rise.

As regards their controls over temperatures, also, our low and high pressure areas differ in different parts of the country. In the east, the differences between the temperatures in front of a well-marked cyclone and those in the rear, in front of the advancing anticyclone, may be 50° or 60°, or more, in winter. Elsewhere, as on the Pacific coast, or in the south, for example, where the physical conditions are different, and where the cyclones and anticyclones may be less emphatic, or differently associated, the temperature controls are very much less marked.

REGIONAL AND SEASONAL WEATHER TYPES OF THE EASTERN UNITED STATES.—*Winter Weather Types of the Eastern United States.*—The general series of weather changes during the passage of a well-developed winter cyclone and a following anticyclone over the eastern United States in winter is about as follows: a gradual clouding in advance of the storm; increasing northeasterly, easterly, or southerly winds; rising temperature, often bringing unseasonable warmth and even resulting in a thaw in northern sections; rain or snow; a change in wind direction to westerly and falling temperature, with clearing weather. If the cyclone and anticyclone are near, well-developed, and moving rapidly, this sequence is well-marked; the wind changes are distinct; the wind velocities high; the temperature-variations sudden and large; the precipitation heavy. On the other hand, all the characteristic weather types are weakened, and may attract little attention, if the cyclonic control is weak or distant. The types also vary with the location of a district to the north or south of the storm path.

In the eastern United States the cold wave is the most striking and most characteristic winter phenomenon. When our storms move rapidly, the southwestern quadrant is usually considerably warmer than the northeastern, the northwestern being the coldest. In a good typical winter case the average temperature east of the Mississippi River and south of the storm centre was 59°; to the west and south of the center it was 35°; in the northwest quadrant it was 15°. From a large number of observations, the writer has determined the temperature-departures in the four quadrants of well-developed winter cyclones in the eastern United States. Taking the temperature at the centre as the standard, the average departures were as follows: northwest, —8.7°; northeast, —5.6°; southeast, +7.3°; southwest, +26°. For winter anticyclones the results were: northwest, —5.1°; northeast, —3.3°; southeast, +8.9°;southwest, +7.°. In general, the average rise of temperature in front of a winter storm in the eastern United States is not far from 10°, but may reach 20°-30° above the seasonal normal. Stations which happen to be on the northern side of a passing cyclone have northerly instead of southerly winds, and therefore do not experience such marked temperature-changes as are noted at stations south of the storm path.

The rapidity and amount of fall of temperature in the rear of a retreating cyclone depends upon the development, paths, velocities and relations of the existing low and high pressure areas. In winter, when our cyclones have passed to the eastward of the Rocky Mountains, they are usually followed by anticyclones which press southward behind them from the northwest. When, for example, an energetic cyclone is moving east, along the southern circuit, and a well-marked anticyclone with low temperatures follows it, advancing

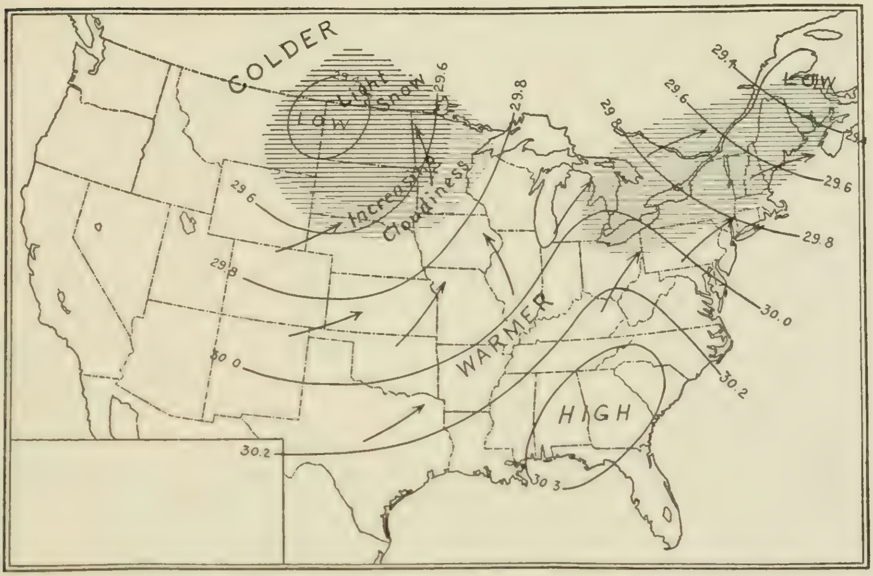

FIG. 5.—North Western (Alberta) Type, first day.

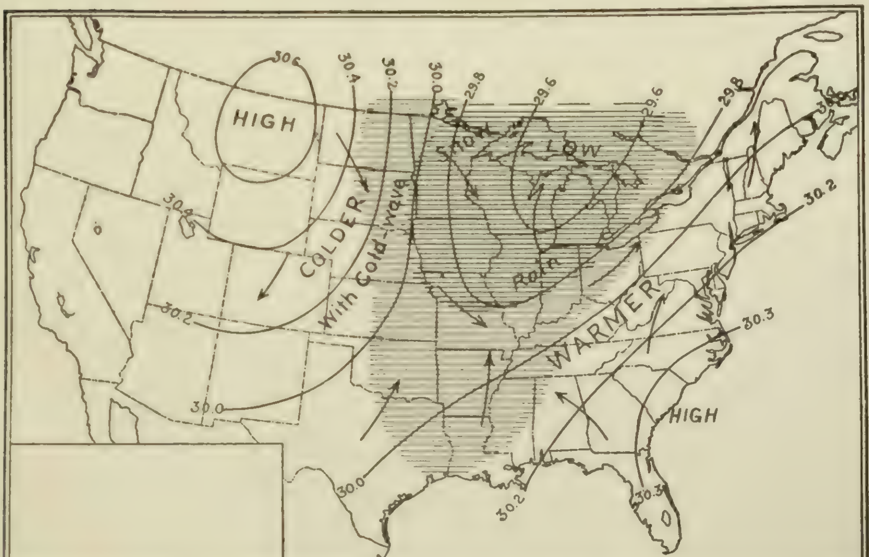

FIG. 6.—North Western (Alberta) Type, second day.

from the northwest, the conditions are most favorable for severe cold in the southern States. If, in the absence of a low pressure area over the southern States, the anticyclone follows the northern circuit, the fall of temperature is less severe, and extends less far southward. When a high remains stationary over the northern Rocky Mountain-Plateau region, there is not much likelihood of severe cold waves east of these mountains. The number of possible combinations of cyclones and anticyclones in the production of more, or less, severe, and of more, or less, extended cold waves, is very large. Discussion of these combinations is out of place here. Without a preceding energetic low, an anticyclone will not bring as great a fall in temperature as with it. The more rapid the progression of the low, other things being equal, the more rapid the fall in temperature. Cold waves in the North Atlantic States and in New England occur in the rear of a retreating cyclone, followed by a high moving east or southeast from the northern Plains. In general, there is a gradually decreasing intensity of cold when marked highs have moved from the northwest into the southern States and then turn east or northeast. Thus the eastern sections, under these conditions, may have modified cold waves.

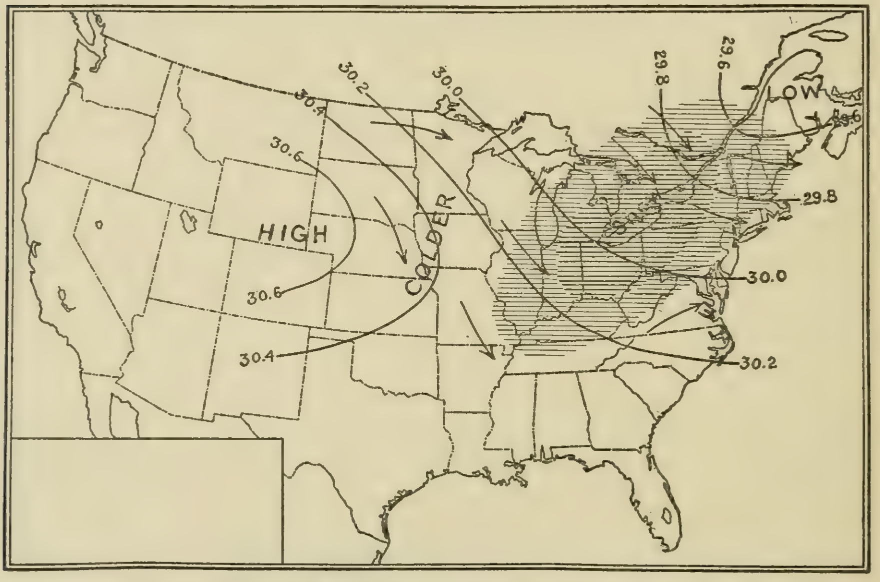

FIG. 7.—North Western (Alberta) Type, third day.

When our winter storms of the northwestern ("Alberta") type first appear on our weather maps they usually cause little precipitation, and that mostly in the form of snow in their northern and northwestern quadrants, over the northern Rocky Mountain region. The temperature is then rising, as a rule, west of the Mississippi

River, with southerly winds, but falling in the northwest with northerly winds, and the cloudiness is increasing over the northern Plains. In twenty-four hours, more or less, the storm, meanwhile increasing in intensity, is likely to be over the upper Lakes, attended by more precipitation, which may be in the form of heavy snows, and often by severe southerly or southwesterly gales. Over the central valleys and to the eastward the temperatures rise perhaps 20° to 30°, and with the warmer weather come clouds and rain at the southern, and probably snow at the northern stations. Colder, clearing weather—perhaps a well-defined cold wave—follows the storm centre with northwesterly winds, overspreading the northern tier of states from the Rocky Mountains to the Lakes. On the third day the storm centre usually reaches the vicinity of the Gulf of St. Lawrence, perhaps still further increasing in energy; the area of rising temperatures with snow or rain extends to the Atlantic coast; falling temperatures with clearing northwest winds are noted across the central valleys and to the eastward. Snow, with westerly gales, often continues for some hours at stations on the lower Lakes, and storm warnings, of high southwest, west and northwest winds are frequent under these conditions along the northern Atlantic coast. As the storm centre moves off beyond the range of the weather map, the clearing and colder weather overspreads the northeastern sections. After a day or so the cold begins to moderate over the central valleys, the weather continuing fair until controlled by the next cyclone. Figures 5 to 7 illustrate weather conditions of common occurrence around a cyclone of the northwestern type during its progress across country.

Our "northwestern" storms are not our greatest rain-bringers in the eastern United States. Precipitation is generally light, and on their western side, until they reach the upper Mississippi Valley and the Lakes, when the rainfall becomes heavier and is found in the eastern quadrants, especially to the southeast of the centre. Further, these storms are generally unfavorable to precipitation over southern sections, which are likely to be outside the limits of rainfall. Extended cyclones of this type, as well as of the other types, may, however, cause stormy weather over practically the whole country east of the Rocky Mountains, carrying their cold and their rains as far south as the Gulf of Mexico. A succession of northern circuit storms tends to cause a spell of dry weather in the south. At the same time the warm southerly winds, flowing northward over the states which lie south of the storm path, bring high temperatures to those sections. One other feature of this same type of storm is its tendency, not infrequently, to be accompanied and followed by a generally unsettled condition, extending as a long trough across the central valleys to the Gulf of Mexico. Such a pressure distribution is likely to develop secondary storm centres, and to lead to a somewhat prolonged period of rainy and cloudy weather over eastern sections.

Storms of the "North Pacific" type which have crossed the northern portion of the interior province,[8] and then follow the northern circuit, do not differ essentially in the weather types which they produce over the eastern United States from those of storms of the Alberta type. (Figs. 5-7.) Fig. 8 illustrates a North Pacific type storm when it is controlling the conditions over the northern Pacific Slope,[9] before it moves east across the mountains. From the northern circuit, in common with a number of storms of the Alberta type, some of this North Pacific group loop southwards when east of the Rocky Mountains, and then turn northeastward to the Lakes and New England. Many North Pacific type lows do not follow the northern circuit, but loop southeastward over the central or southern part of the interior province, perhaps skirting the Gulf Coast on the southern circuit, and then moving northeasterly up the Mississippi Valley (Figs. 9 to 12), or crossing the Rocky Mountains farther north (lat. 35°-45°) and then traveling northeast. The regional weather types differ according to the path and the special characteristics of each cyclone. When the storm follows a low latitude, perhaps crossing northern Texas and Oklahoma, or Louisiana, before turning more directly

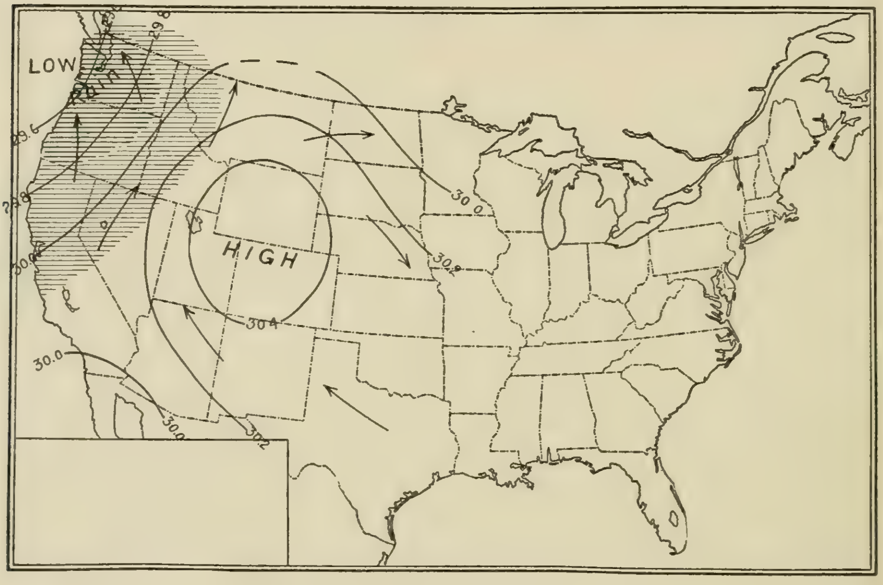

Fig. 8.—North Pacific Type, first day.

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[8] "Interior Province" is that portion of the United States between the Rocky Mountains and the Sierra Nevada-Cascades.

[9] See page 40.

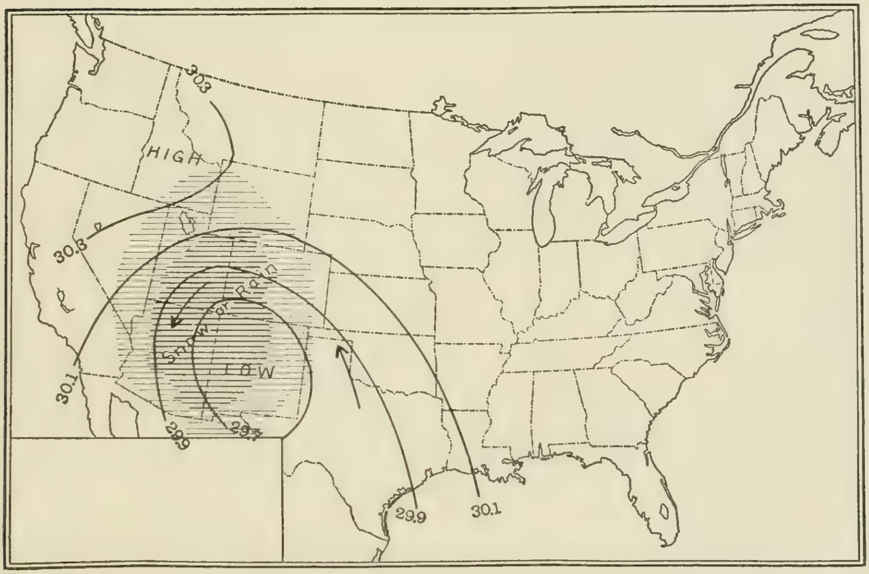

FIG. 9.—North Pacific Type (southern circuit), second day.

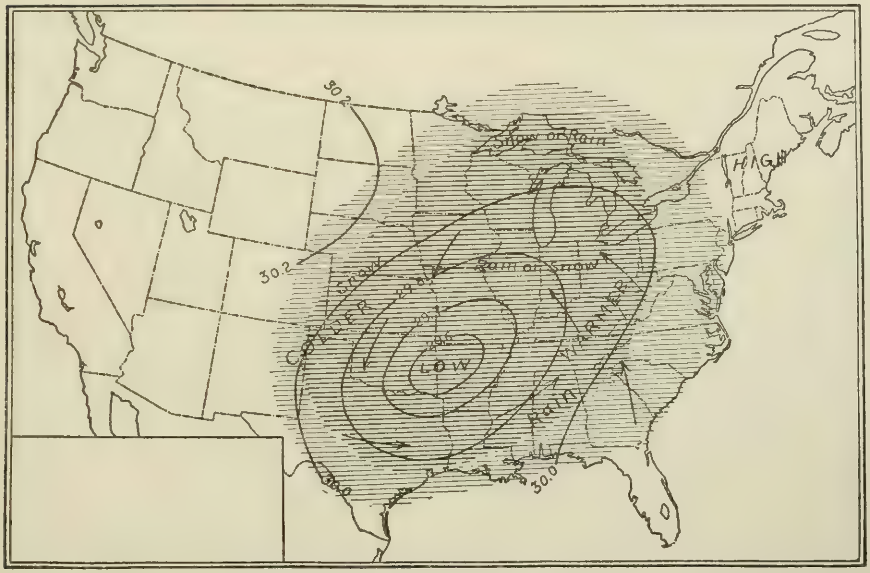

FIG. 10.—North Pacific Type (southern circuit), third day.

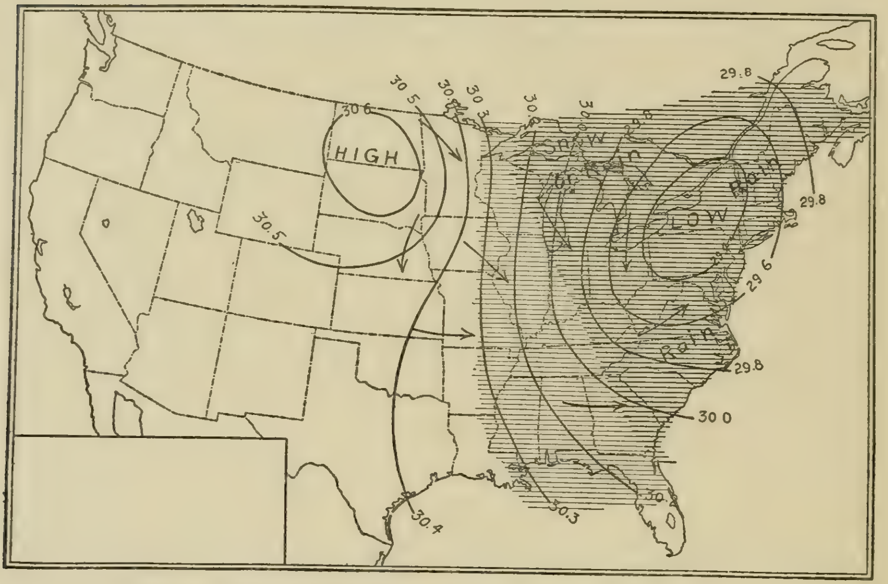

FIG. 11.—North Pacific Type (southern circuit), fourth day.

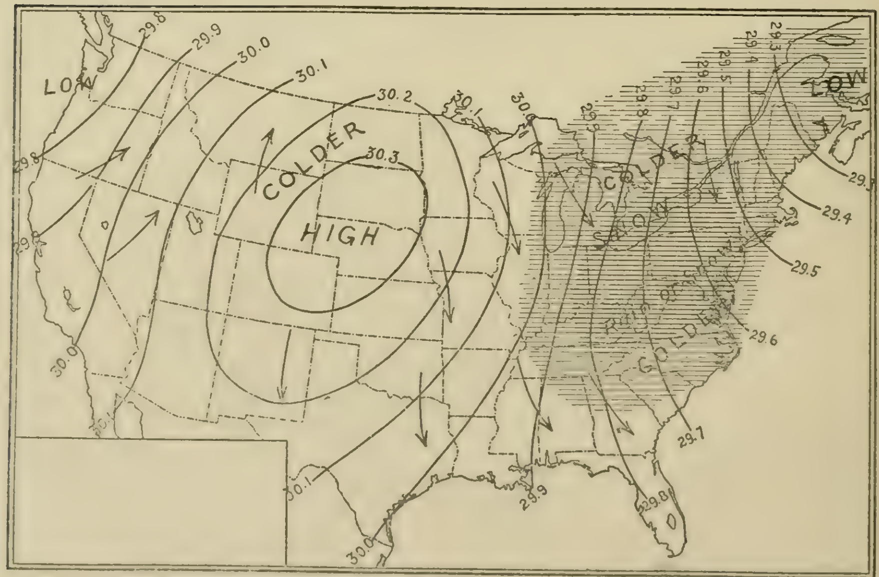

FIG. 12.—North Pacific Type (southern circuit), fifth day.

northeast, the tendency is to extend the area of general precipitation over the southern and southwestern Gulf States, as well as over the more northern sections west of the Mississippi River. A more southerly path also usually means that there will be more rain, or snow, and more cool northerly winds. On the other hand, a more northerly path usually results in less precipitation over the southern states.

From the southwest—from the western Gulf of Mexico and from Texas,—comes a group of cyclones known as the "Southwestern" or "Texas" type, which develop their essential characteristics in that region. Most of them come from the North Pacific coast, across the interior province; some move in from California; some few come through Mexico. Usually moving northeast across the Mississippi, they reach the vicinity of the Lakes or the Ohio Valley in about one day, and New England or the Gulf of St. Lawrence in about another day. Some take the outside route, along the Atlantic coast, for a part or the whole of their northward journey. The most typical and best-marked storms of the "Southwestern" type come in February and last through March and perhaps into April. Their habit is to increase in intensity and in velocity of progression as they advance northeast. They are preceded and accompanied by a decided rise in temperature and by general and usually heavy rains over the eastern United States, east and southeast of their centres, especially over the Gulf and Atlantic Coasts and in the Ohio Valley. When tempera-

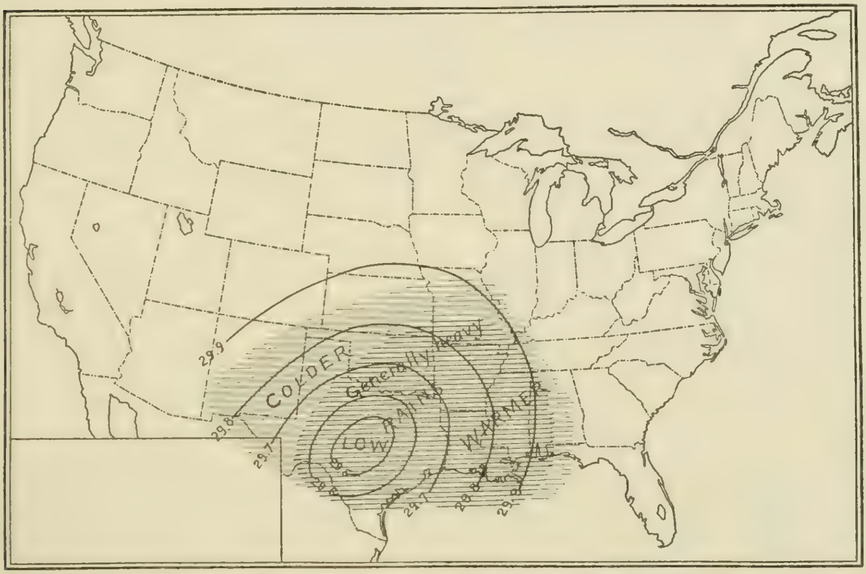

FIG. 13.—Texas or South Western Type, first day.

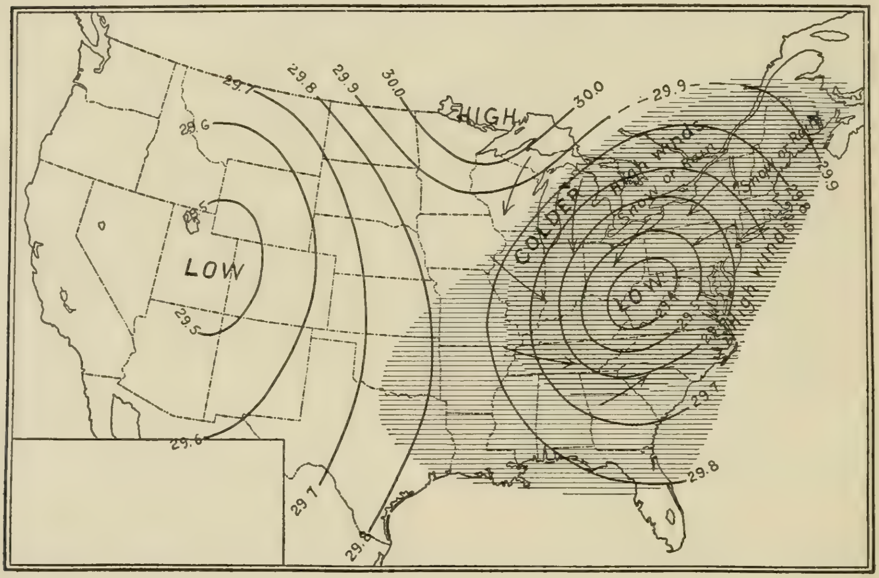

FIG. 14.—Texas or South Western Type, second day.

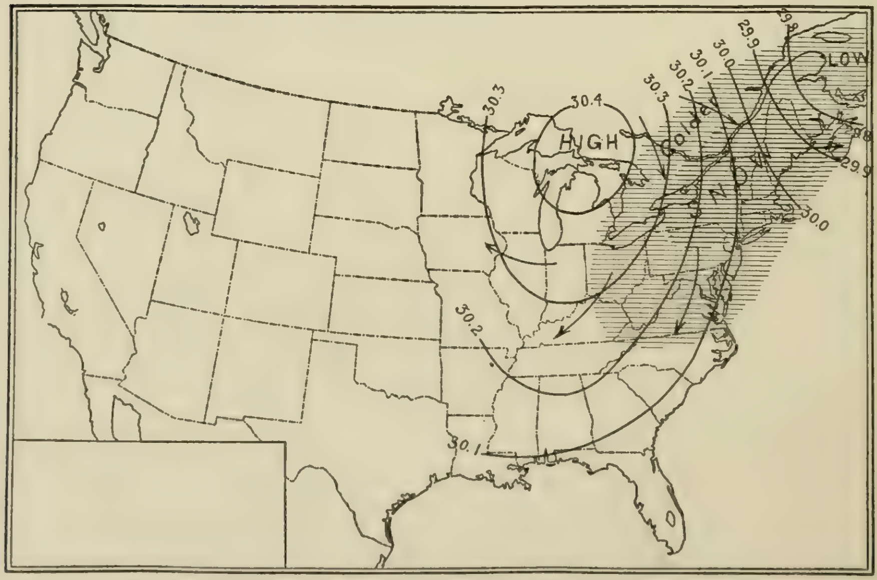

FIG. 15.—Texas or South Western Type, third day.

tures and other conditions are favorable, heavy snows are frequent to the north and northeast. Our first autumn snowstorm in northeastern sections often comes with the approach of one of these southwestern storms. These storms not only rank as heavy rain-bringers, but also belong, as a whole, among the most severe storms of the eastern United States, with their high winds and their marked temperature-differences between front and rear. The extended rain area of a southwestern storm, having already spread over a considerable section of the Gulf States, and even of the Great Plains, may cover the lower Mississippi and Ohio Valleys in the first 24 hours after the development of the low over the western Gulf, and then reach the Atlantic Coast and the New England States in the second 24 hours. Over the Great Lakes and the north Atlantic coast storms of this group begin with northeasterly winds, generally increasing to high velocities, and backing to the northwest. Gales dangerous to navigation over northeastern sections are frequent under these conditions, and storm warnings are usual at such times. A high from the northern plateau, or eastern Rocky Mountain slope, usually follows the storm, drifting first south and then northeast, acting with the low to produce the fall in temperature. A marked high on the north Atlantic coast sometimes blocks the storm, and changes its path. Figs 13 to 15 illustrate weather conditions which are fairly characteristic of southwestern storms as these disturbances progress from the western Gulf of Mexico to the Gulf of St. Lawrence.

Storms of the "Colorado" type begin their weather controls in the eastern United States by causing unsettled weather with precipitation, which may be in the form of general rains or snows, or of scattering showers, or thunderstorms (in the warmer months), over a considerable area between the Mississippi River and the Rocky Mountains. To the north of the centre rain or snow falls with northerly winds. Moving eastward toward the Lakes, these storms usually increase in intensity; their precipitation area advances to the Atlantic coast; they are preceded by rising and followed by falling temperatures. Such a storm when over the Lakes may give general rains over the entire area east of the Mississippi, with snow in the north, gales and storm warnings. Often, however, while the rains or snows may be fairly general over the northern half of the country east of the Rocky Mountains, the precipitation area does not extend into the southern tier of States. There the effect of the storm may be merely to raise the temperatures in front and to cause fair to cloudy weather, followed by clearing and cooler in the rear (Figs. 16 to 18).

Storms moving northeast along the Atlantic seaboard, whether coming from the Gulf of Mexico, or first appearing on our weather maps off the middle or south Atlantic coast, are popularly known as "coast

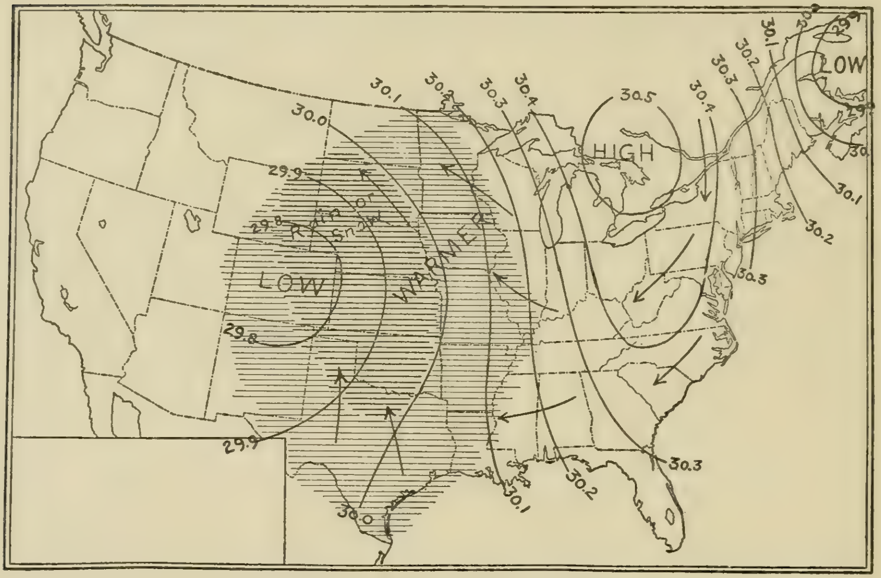

FIG. 16.—Colorado Type, first day.

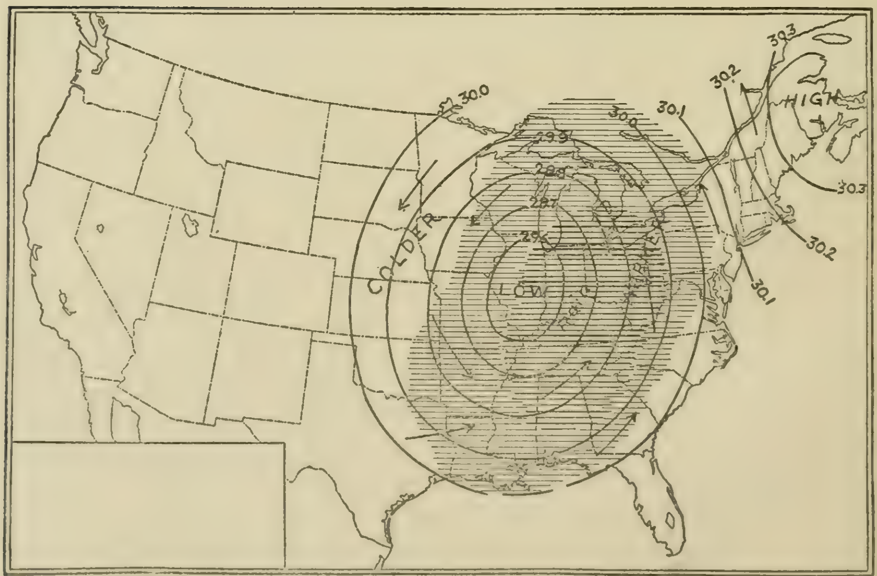

FIG. 17.—Colorado Type, second day.

storms." While not, as a rule, causing stormy weather over a large part of the mainland, these coast storms are often severe, bringing heavy rains over the eastern Gulf and south Atlantic States and (in winter) heavy snows over northeastern sections, with easterly changing to westerly gales at sea and along the coast. When snow falls, these high winds are a serious handicap to the railroads and to electric car lines because of the heavily drifting snows. Our coast storms are usually followed by rapidly falling temperatures, with high northwesterly winds (Figs. 19 and 20).

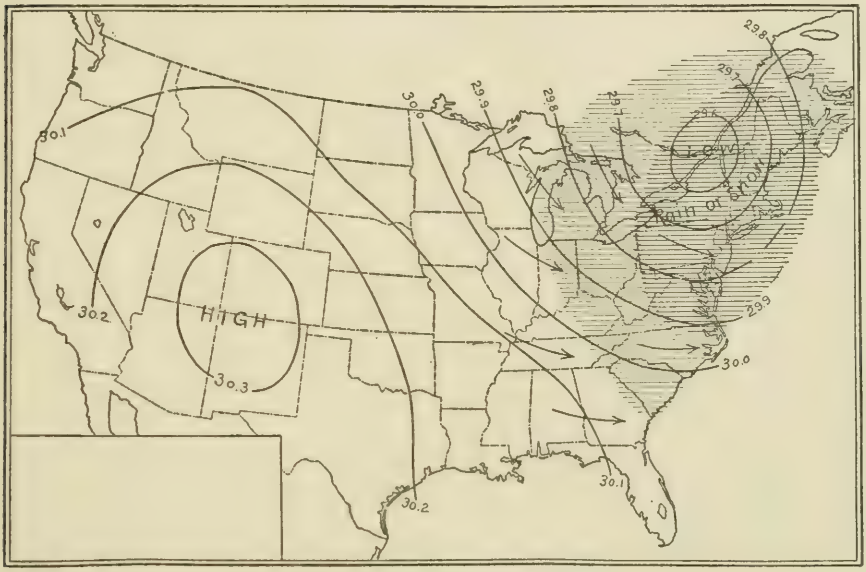

FIG. 18.—Colorado Type, third day.

Although we have been devoting our attention to the weather types which are controlled by cyclones, and by the anticyclones which are most closely associated with them, we should not forget that our weather controls are not always dominated chiefly by low pressure conditions. Not infrequently an immense area of high pressure may cover most of the country, in summer as well as in winter, and clear or fair weather prevail over practically all sections, with more or less marked typical diurnal variations in temperature. In spring and autumn such conditions are often favorable for frost. Fig. 21 illustrates the far-reaching influence of an immense anticyclone central over the northern Great Plains. After the disappearance of the retreating cyclone in the northeast, the anticyclonic control becomes dominant over practically the whole country.

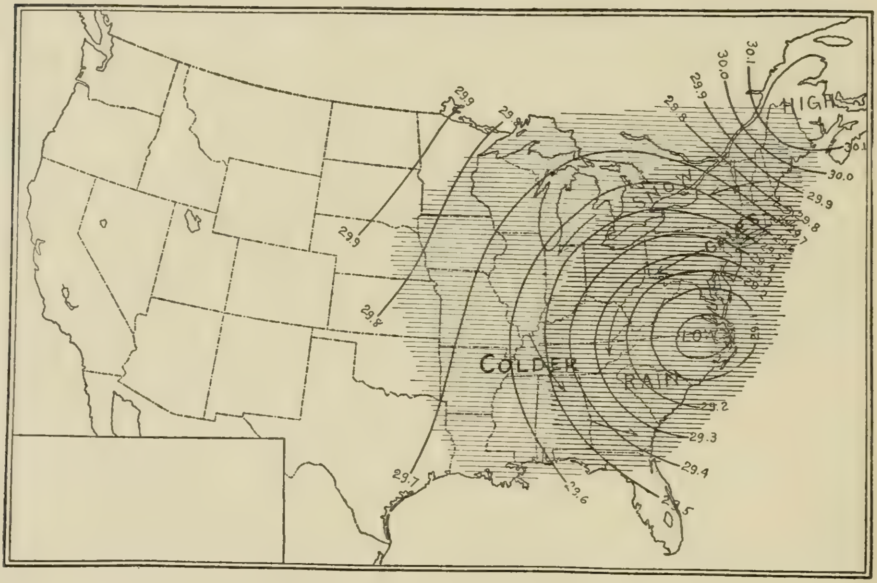

Fig. 19.—Coast Storm, first day.

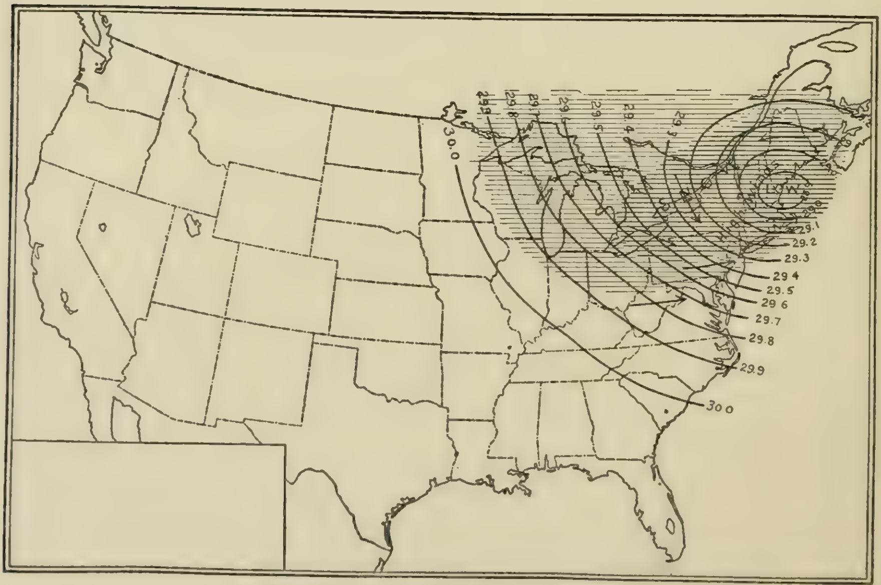

Fig. 20.—Coast Storm, second day.

Summer Weather Types of the Eastern United States.—Summer weather in the eastern United States is generally peaceful and uneventful. It is frequently marked by periods of stagnation of the lows and highs. A weak summer cyclone, usually without a widespread cloud area, passes along the northern circuit, followed by an area of high pressure which moves off the middle Atlantic coast. On the northward gradients in front of the approaching low is a belt of warm, muggy, southerly winds, which spreads eastward as the low advances. The temperature rises higher each day for several days in succession, reaching maxima which cause great suffering and many deaths, especially in our crowded cities. Often these hot spells are cloudless, the sun blazing down with relentless fury undiminished by so much as a single cloud. Thunderstorms, following the increasing growth of cumulus clouds, are common during these hot southerly spells, especially at the time when the winds in the rear of the retreating low shift quickly to northwesterly. Under these latter conditions there follows a welcome fall in temperature in the brisk, cool northwesterly winds. The high advances from the west. The winds soon decrease in velocity. There comes a short spell of clear and cool weather, with marked diurnal variation of temperature, giving pleasantly refreshing nights. Occasional showers may fall on the margins or towards the centre of the high, and soon the approach of another cyclone starts the whole succession of weather types over again. Variations on the general theme occur as the cyclonic and anticyclonic controls differ in

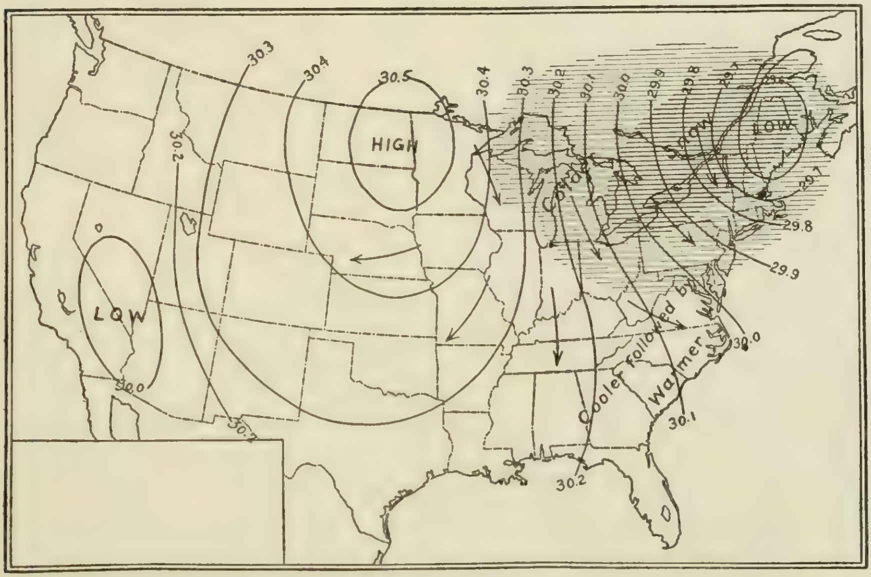

FIG. 21.—Dominant Winter Anticyclone.

each case. There are no two series of these weather types exactly alike. That fact adds an interest to weather study which frees it from all trace of monotony.

In summer, most of our rain over the eastern United States falls sporadically, in thunderstorms, which are especially large and well developed from the Mississippi Valley to the Atlantic. While these thunderstorms are usually of short duration, they are often violent, and give heavy rainfalls in a short time. A summer month with heavy rainfall is likely to be a month with numerous and well-marked thunderstorms. It must not be supposed that general storm rains are entirely absent from the eastern United States in summer. Widespread and severe cyclonic storms are rare, but occasional lows, on whichever path they travel, may give general precipitation, especially over the northern states east of the Mississippi River but also extending into the middle tier of states to the south. Such general rains are often most beneficial agents in breaking a long spell of drought over the great wheat and corn belts of the west.

A very characteristic summer weather map shows a well-marked anticyclone over the south Atlantic and eastern Gulf States. This is really a westward extension of the sub-tropical high pressure area of the north Atlantic Ocean. Down the northward gradients of this anticyclone flows a great body of southerly winds, especially when the gradients are reinforced by the presence of a cyclone advancing eastward on the northern circuit across the Lakes and down the St. Lawrence. These conditions give us our most severe summer hot waves over the interior valleys and the eastern districts. The pressure gradients which produce hot waves are thus the reverse of those which bring cold waves. The larger and better developed the anticyclone, and the longer it remains stationary, the more severe and the longer lived is the hot wave; the less the chance of local showers. The weaker the anticyclone, and the more its control is overcome by occasional low pressure areas from the west, the more frequent the interruption of the hot wave by thundershowers and cooler westerly winds.

Spring Weather Types of the Eastern United States.—Spring weather types are, as has been noted, transitional between winter and summer. Thus, in late winter or early spring a pressure distribution of the hot wave type, just described, is a clear indication of the coming of warm-season conditions. Occasional cyclones from the south, with chilling northeast winds and cold rains or snows in eastern sections, are unpleasant reminders that winter has not wholly lost its grip. Especially severe are such storms when the southern low unites with a low coming east on the northern circuit, the two joining somewhere on the northern Atlantic coast, and giving high winds and heavy precipitation, which may be snow or rain according to the temperatures. If such a storm "hangs fire" on the coast, as happened in the case of the famous "March blizzard" of 1888, the resulting precipitation is unusually heavy. Winds from the cold continental interior bring wintry temperatures at intervals in the midst of warm, spring-like weather types.

Spring advances from the far southwest, gradually spreading north and east, and starting into activity all the varied agricultural and outdoor occupations which have waited through the turbulent winter months of our northern States for the return of summer. It is in the northeast that winter lingers longest, about the cold waters of the Great Lakes, and in northern New England. Our spring frosts, coming under clear anticyclonic skies, are so emphatic a type that there is little difficulty in forecasting their occurrence from the daily weather map. Destructive spring frosts obviously suggest weakening winter controls, but April showers, often really nothing but embryo thunderstorms, presage summer.

Autumn Weather Types of the Eastern United States.—Autumn brings many of the most satisfying days of the whole year—those bright, clear, bracing days, under high pressure control, with their warm noon hours, followed by crisp, even chilly, nights, with frequent autumnal frosts of increasing severity, and the characteristic nocturnal valley and lowland fogs of our colder season. There are few more glorious spells of weather than those which we call our *Indian Summer,* with their light, balmy southerly breezes blowing northward from an anticyclone over the south Atlantic States; their soft and hazy skies; their touch of summer warmth which they bring back to us after we have already begun to feel the keen bite of winter cold. Real summer spells these are,—and they are the last until the following spring, wedged into the midst of the storms which are then becoming increasingly frequent and severe, and of cool waves which are soon to become cold; and delaying, temporarily at least, the advance of winter.

Our autumn cyclones, most of them following the northern circuit, take on their winter habit of greater violence and of more rapid progression over more southerly latitudes. Not a few of them, however, still bear the summer earmarks of a deficiency of precipitation, but their inflowing winds of increasing velocity, and their extended cloud sheets and general rains, or even snows, make it more and more difficult for the sun to control the temperature. Gales and the number of rainy days increase over the Great Lakes and in northeastern sections, because those districts are near the storm centres, whose control does not extend as far southward as is the case later in the season. General cyclonic storms—characteristic of winter—show an increasing control over weather as early as September, and to this fact is probably due the widespread, but mistaken, popular belief in an "equinoctial storm."

The West Indian hurricanes of autumn, although smaller than most of our own storms, are more highly developed and more severe, usually cause violent gales and heavy rains along the Atlantic and Gulf coasts, and are destructive to shipping interests, and even to buildings. Fortunately for interior sections, their influence does not extend far inland. The total annual rainfall at many of the stations in these southern coast districts is markedly affected by the occurrence or non-occurrence of tropical hurricanes. When a West Indian hurricane joins, by means of a long trough of low pressure, with a storm from the Great Lakes off the middle or northern Atlantic coast, unusually severe storm conditions are sure to follow, especially along the New England coast. A high, following closely on the rear, is likely to bring rapidly falling temperatures, with snows, in late autumn. In general, however, the temperature-changes accompanying West Indian hurricanes are much less emphatic than those which are characteristic of the winter cyclones which we have been considering, because the former occur near the coast and in the warmer months. Figs. 22 to 24 illustrate generalized weather types during the passage of a West Indian hurricane along our eastern seaboard.

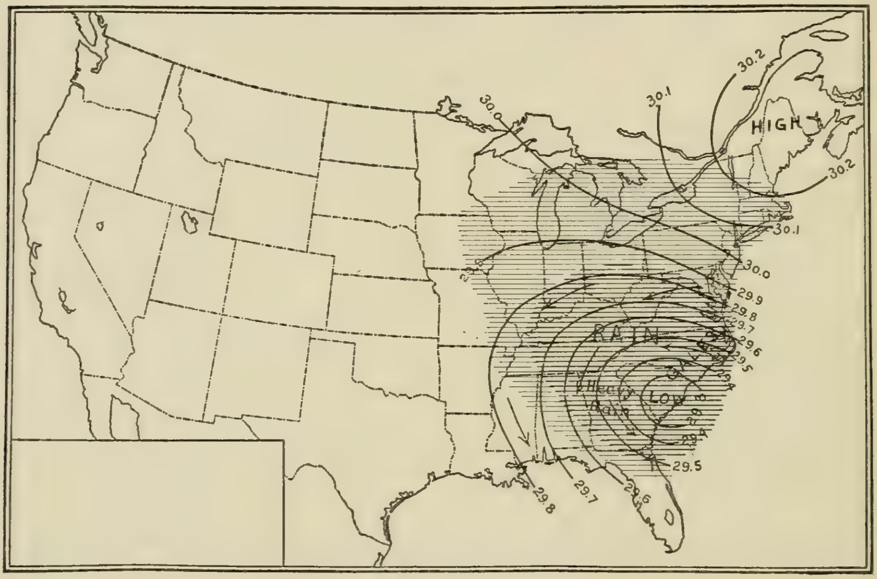

FIG. 22.—West Indian Hurricane, first day.

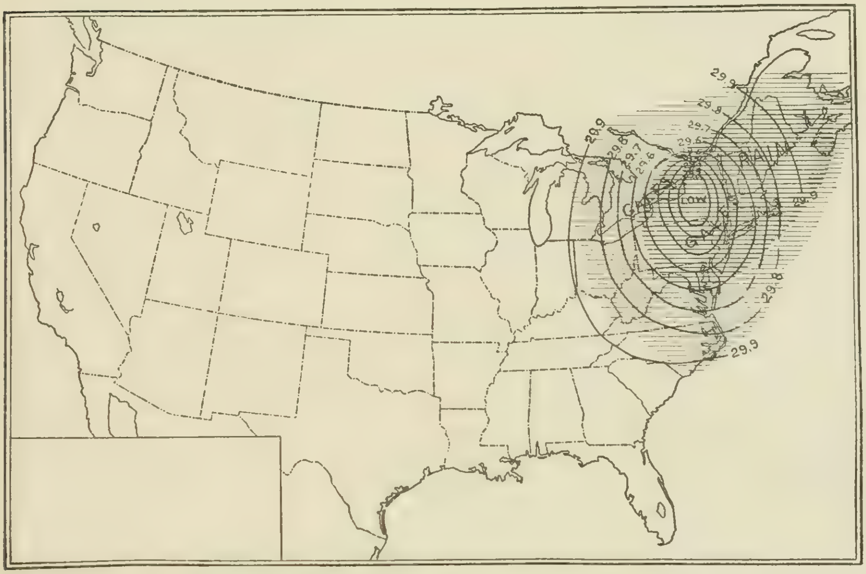

FIG. 23.—West Indian Hurricane, second day.

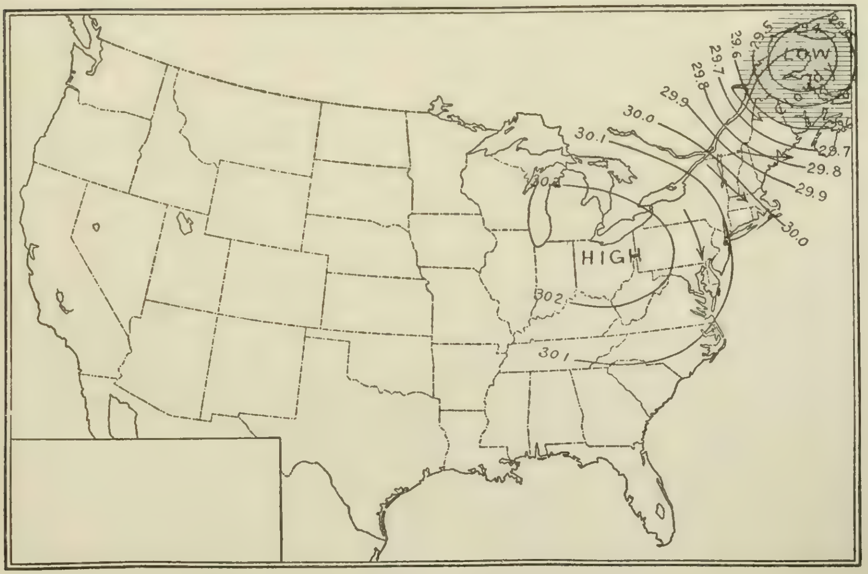

FIG. 24.—West Indian Hurricane, third day.

Curves Illustrating Weather Types of the Northeastern United States.—The characteristics of some of the more common weather types of the eastern United States may be better appreciated through an examination of a series of curves, selected to illustrate typical conditions of frequent occurrence. The curves here shown were recorded on the thermograph and the barograph of the Jackson Company, of Nashua, N. H., a representative New England station, and were chosen because New England, as a result of its peculiar position in relation to cyclonic paths, offers unusually favorable opportunities

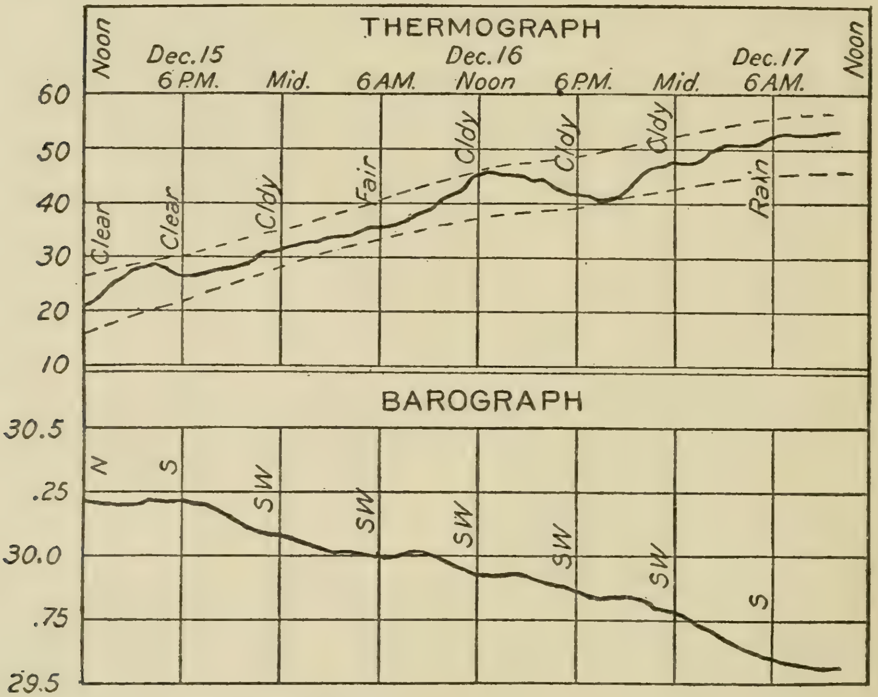

FIG. 25.—An excellent illustration of the cyclonic control of winter temperature changes. With the approach of a winter cyclone warm, damp, cloudy, southerly winds ("sirocco") cause a decided, though gradual, rise of temperature, which is entirely independent of the time of day. The maximum on December 15 comes at midnight; the rise of the temperature belt continues over night of the 15th, through the 16th and into the morning of the 17th, bringing a decided winter thaw which is helped by the warm rain of December 17th. Under such conditions of high temperatures, our heavy winter clothing and our overheated houses are uncomfortable. Warm rains, like those indicated on December 17th, are likely to cause freshets if prolonged, especially when the ground is deeply covered with snow. A slight cooling appears in the early night of the 16th, but the temperature belt as a whole is very narrow. Notice particularly the fact that on December 16 the minimum temperature comes at the first midnight and the maximum at the second midnight, *i. e.*, the "diurnal range" is cyclonically controlled.

for studying cyclonic control of weather and climate. The illustrations which follow are taken from material in the Climatological Laboratory of Harvard University, whose preparation was originally suggested by Professor William Morris Davis. The state of the sky is indicated along the thermograph curves. The wind direction is shown along the barograph curves. The distance between the broken

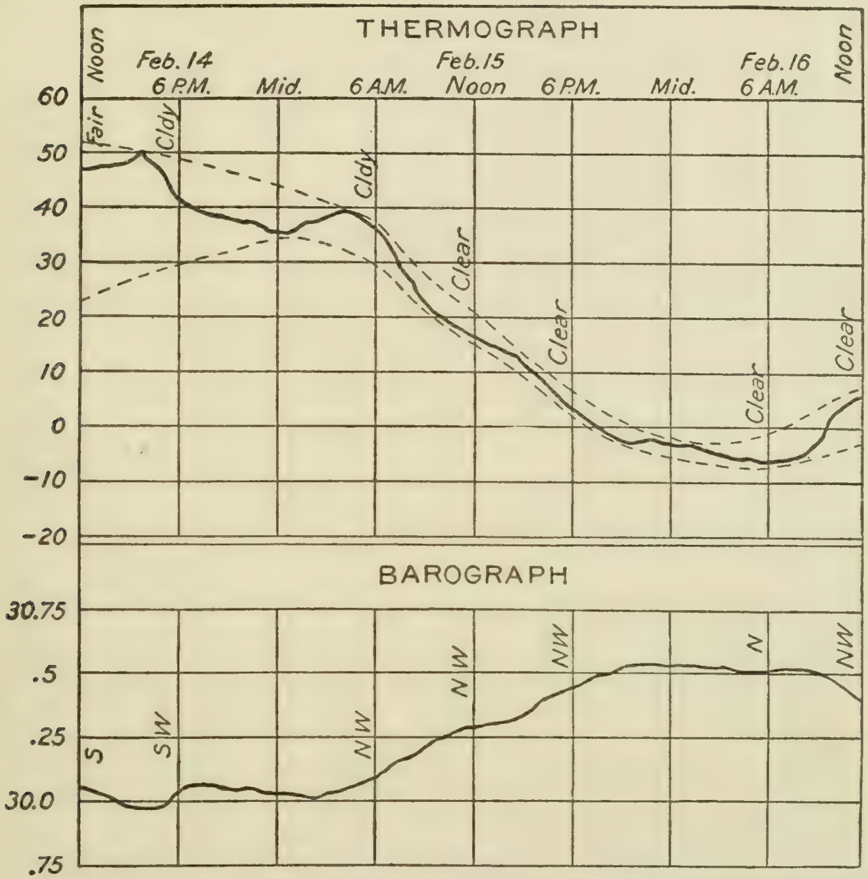

FIG. 26.—February cold wave. A maximum of 50° is reached under the warm, damp, muggy, southerly winds of a passing winter cyclone (compare Figs. 25 and 27). With a shift of wind into the northwest, a rapid fall of temperature (cold wave) takes place, from the early morning of one day (February 15), through noon, with hardly any trace of diurnal warming, although the sky is clear, to the early morning of the next day, the minimum coming with the highest pressure, and on a clear night (compare Fig. 27). The cyclonic range of temperature is here very clearly brought out in the drop of the temperature belt from one side to the other of the diagram. It is such sudden temperature changes as these that make it hard for many persons who are not in robust health to endure the winters in the eastern United States. The fall in temperature shown above was over 50° in 36 hours, and during most of that time a strong, biting northwest wind was blowing.

lines which join the crests and the troughs of the thermograph curves shows the amount of the diurnal range (or change) of temperature. The belt enclosed between these lines (temperature belt) rises and falls with the cyclonic or anticyclonic control of the temperature. Although pressure is not an element of importance in climatology, the barograph curve, when employed in such diagrams as these, is a great help in showing the extent and duration of the successive cyclonic and anticyclonic controls. Such diagrams offer abundant and varied exercises

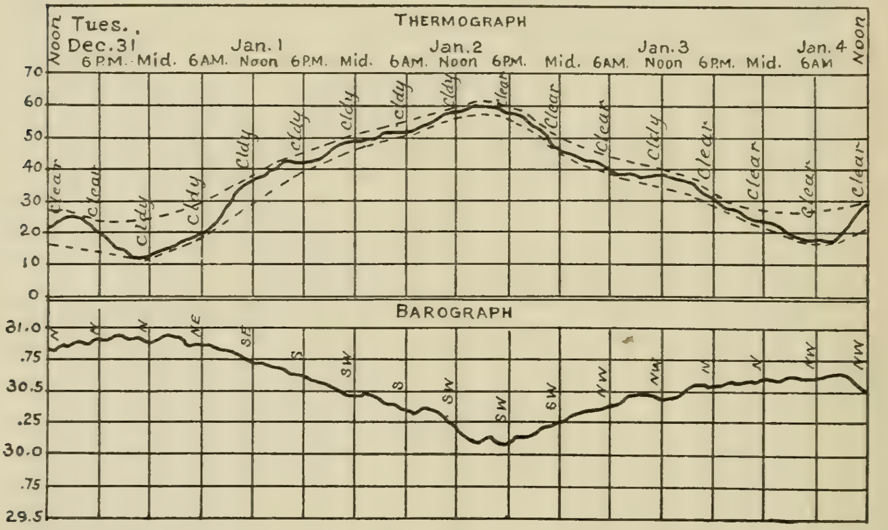

FIG. 27.—A good example of typical winter temperature controls. A marked maximum of about 60° under the control of the warm southwest winds in association with a winter cyclone, with cloudy weather, comes at the time of lowest pressure (compare Figs. 25 and 26). The two minima come at the crests of the two high pressure areas. On January 1 the minimum is at the initial midnight; the maximum is at the final midnight; the "diurnal range" is wholly cyclonic. On January 3 the maximum is at the initial midnight and the minimum at the final midnight; the opposite condition, but again the range is cyclonic. The temperature belt rises and falls as the cyclone or anticyclone may determine. A glance at the thermograph curve on January 1 and 2 shows how completely the diurnal control has disappeared. The cyclonic rise of temperature on January 1 begins as the northerly and preceding northwesterly winds weaken.

for discussion in laboratory work, and give a clearer and more accurate view of the complexity of our climates than can be obtained from any of the normal climatic tables. If a series of similar curves were provided for different stations in other parts of the United States, the teaching of our local climatology would be greatly simplified, stimulated and improved. Each weather type has its own special and characteristic economic and human responses. An understanding of these types is often of great help in making individual weather forecasts.

for two or three days ahead, and in preparing oneself to guard against the unfavorable effects of the different types, as well as to profit by the favorable effects. As any such type curves remain type curves, whenever they are recorded, the year of occurrence obviously matters little. The curves are arranged by seasons, and the most important facts are noted in the text accompanying each figure.

Each Section has its own Weather Types.—The accompanying curves relate to one station only, in New England, but the weather types which they illustrate are found, more or less modified, over most of the eastern United States. In the southern States, with increasing distance from the most frequented cyclonic paths, the cyclonic control is naturally weaker; the diurnal phenomena are more marked and more characteristic, even in winter; the changes in winds and temperature are rather less sudden, less frequent, less violent. Thus, e.g., in winter, during the passage of a well-developed cyclone along the northern circuit, the southern states may have all their winds from a southerly direction with but little cyclonic control of temperature, while the more northern states have a sudden shift from southerly to northwesterly winds, with a cold wave. Again, the cloud and rain areas of cyclones crossing the northern tier of states often do not extend as far as our southern stations. The latter therefore have clear or fair weather, or perhaps a brief shower, while farther north there may be heavy and long continued rains. In winter it very

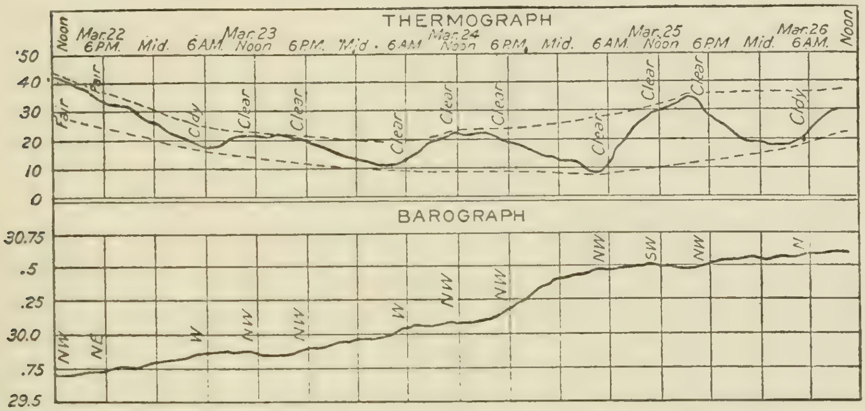

FIG. 28.—Under the active, cool, and dry northwest winds in the rear of a March cyclone the temperature belt is narrow (small diurnal range), because the imported cold cannot be overcome by the noon warming produced by the sun. With the approach of the centre of the high, and with light variable winds, the diurnal range increases; the temperature belt therefore widens; the axis of the belt as a whole rises, and the cold becomes less severe. On March 24 and 25 the warming begins before the highest pressure arrives: a sign of spring.

frequently happens that snow falls in the north, while the higher temperatures of the lower latitudes bring rain instead of snow. The chilling northeast winds felt on the north Atlantic coast when a cyclone is approaching from the south are not experienced far inland, or far south. Again, in summer, it is likely that the northern tier of States will enjoy the cool waves which come on the rear of our weak summer cyclones, while farther south there is no break in the heat brought by the southerly winds. Modifications such as those here suggested, and many others also, result from differences of latitude; of topography; of exposure to winds from the ocean, or the Gulf, or the Great Lakes; of altitude, and from numerous other controls. Each district has its own varieties of weather types. It is sufficient, for our present purpose, to illustrate some of the more important general types as

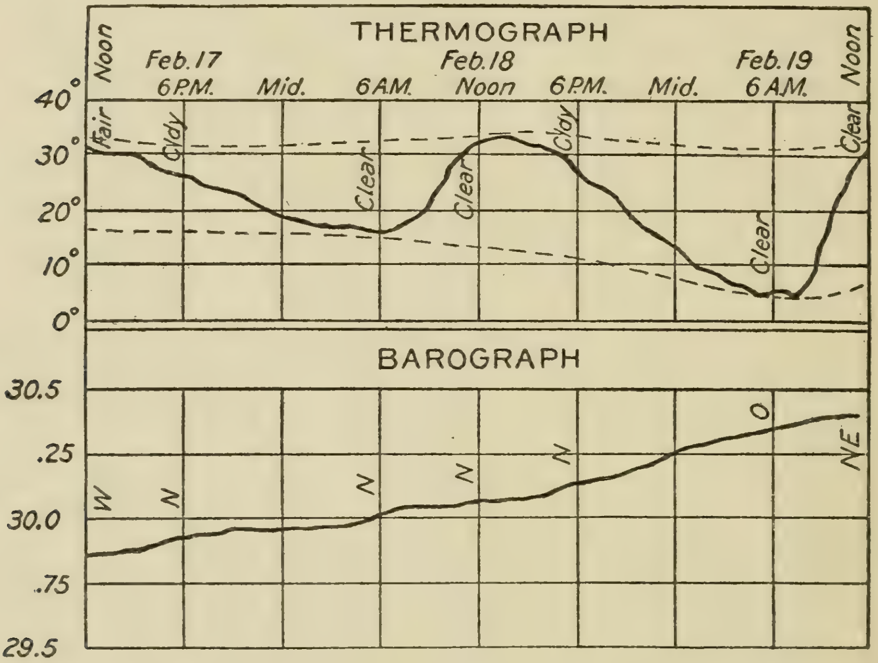

FIG. 29.—Under the light winds of a winter anticyclone we find a moderate winter noon temperature (February 18), the result of a fairly well-marked diurnal range (for winter), and a long, cold night, under clear skies and with no wind. Under such conditions our most marked inversions of temperature occur, the valleys and lowlands having the lowest thermometer readings, while adjacent hill-tops or slopes may have distinctly moderate temperatures. The contrast between the noon temperature (over 30°), and the early morning temperature (5°) emphasizes the general character of such a winter anticyclonic day, with its agreeable noon and early afternoon, and its chilly night. Notice the widening of the temperature belt toward the centre of the anticyclone.

these occur in New England. The almost endless series of modifications as they occur in other sections of the country we cannot undertake to discuss further.[10]

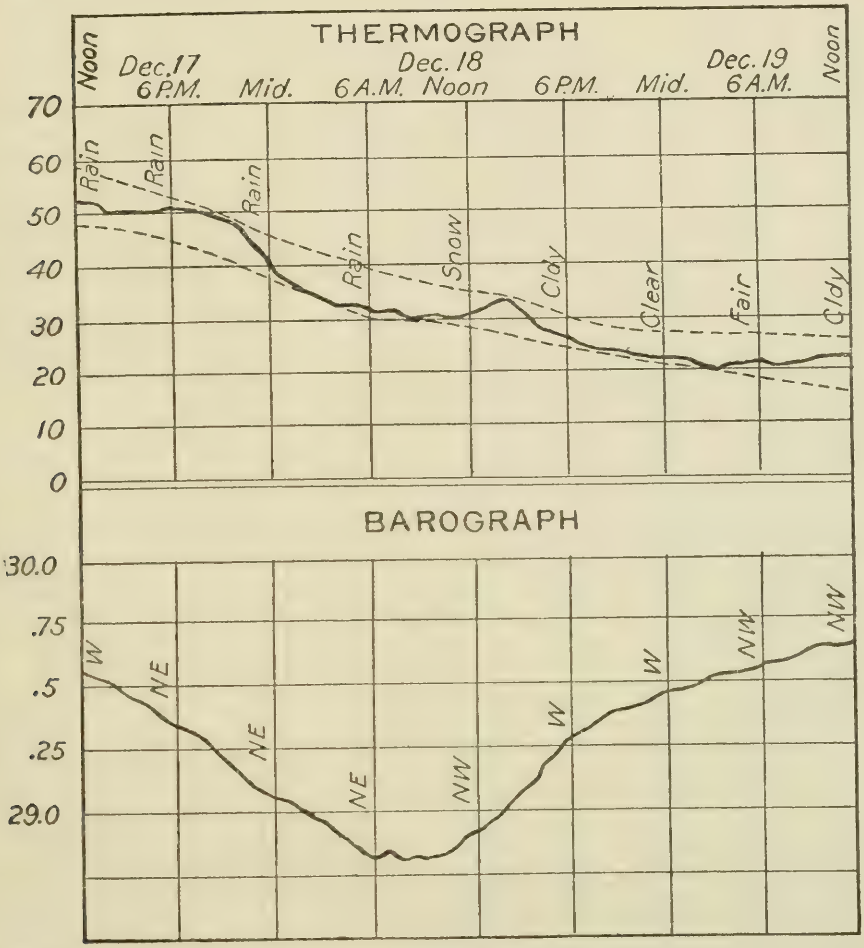

FIG. 30.—A marked fall in temperature under the chilly northeast winds before the passage of a well-developed winter cyclone, with an almost steady fall through noon (December 18) as the result of the imported cold in the westerly winds on the rear of the cyclone. On December 18 the maximum temperature came at the first midnight and the minimum at the second midnight—a striking example of the completeness of the cyclonic control. On December 18, the rain changed to snow as the temperature fell to 30°.

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[10] Professor A. J. Henry has given some very instructive curves to illustrate the effect of a difference of latitude upon the weather conditions at five stations situated on the same meridian. (Bulletin Q, U. S. Weather Bureau, 1906, Figs. 1-3, pp. 16-18.) Professor W. M. Davis has presented an excellent description of New England weather types in Annals Harvard College Observatory, Vol. XXI, Part II, 1890, pp. 116-137.

Regional and Seasonal Weather Types of the Western United States.[11]—*Winter Weather Types of the Pacific Coast.*—Turning now to the western United States, we find the winter and summer types on the Pacific slope as strongly contrasted as, although differing considerably from, those in the East.[12] All winter long a procession of storm areas keeps moving eastward across the northern Pacific slope, generally following the international boundary fairly closely to beyond the Rocky Mountains, and continuing thence on the usual paths. Temperatures about normal; mild southerly winds; rains over Washington and Oregon; cloudy weather and showers perhaps extending into California as far as San Francisco, or beyond: these are the usual conditions when a winter storm is over Washington or Oregon.[13] With steep gradients, southerly gales occur along the coast from Cape Mendocino to Vancouver Island, and brisk south-

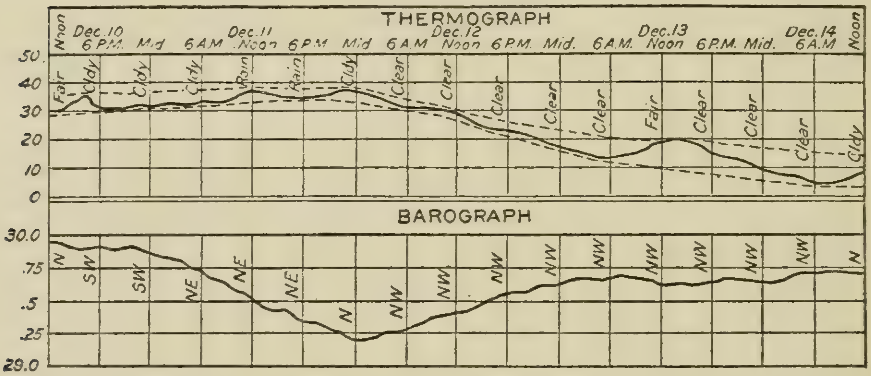

Fig. 31.—In this curve we have only a moderate cyclonic range of temperature, because the cyclonic centre passed to the south of the station, and thus the warm southerly winds (noted in Figs. 25, 26, and 27) were lacking (cf. Fig. 30). The cyclonic clouds and rain resulted, as, usual, in practically extinguishing the diurnal range and thus greatly narrowing the temperature belt. The maximum temperature comes with the minimum pressure, as is usually the case in winter. The cold wave on the rear of the cyclone carries the temperature belt down (compare Figs. 26, 27), the downward slope being but slightly interrupted by a weak diurnal maximum in the afternoon of December 13. On December 11 the chilly northeast winds gave a disagreeable spell of cold, rainy weather.

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[11] The writer is indebted for helpful criticisms on these sections to Messrs. E. A. Beals, F. H. Brandenburg, Ford A. Carpenter, Alexander G. McAdie, and William G. Reed.

[12] B. S. Pague and S. M. Blandford: "Weather Forecasting and Weather Types on the North Pacific Slope." Portland, Oregon, 1897. W. A. Glassford: "Weather Types on the Pacific Coast," Bull. 5, Cal. Acad. Sci., Aug. 31, 1886. Explanatory and descriptive notes on Portland, Ore., San Francisco and San Diego daily weather maps.

[13] See Fig. 8.

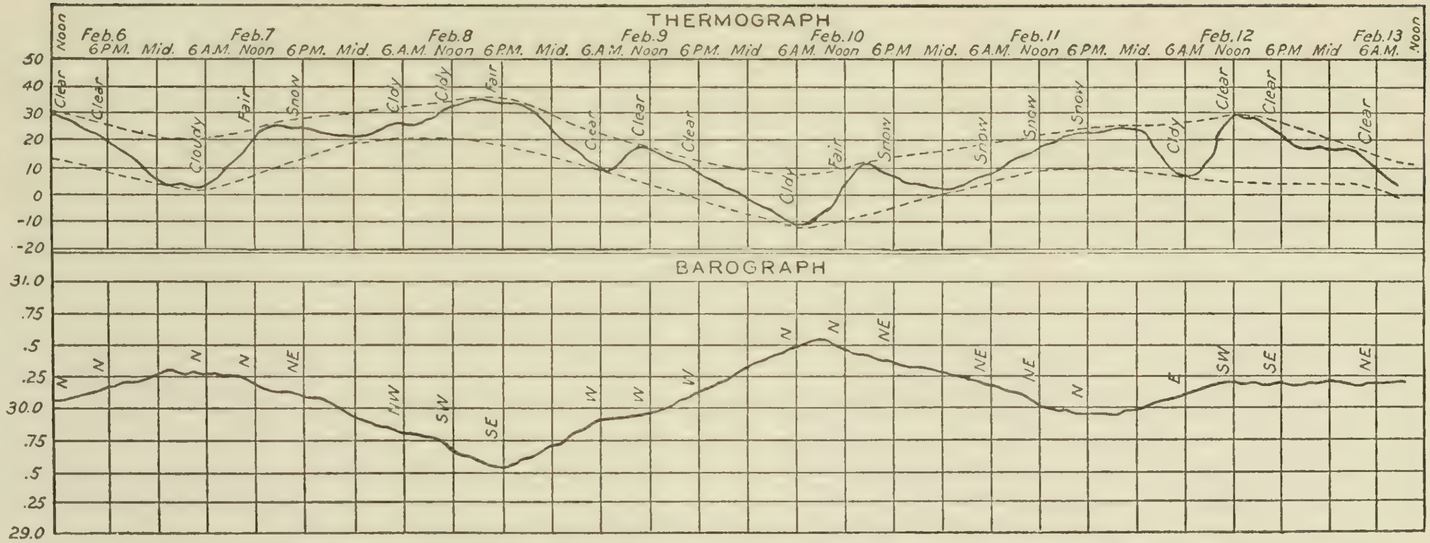

FIG. 32.—Thermograph and barograph curves for a whole week, illustrating the strong ranges and rapid and frequent changes of pressure and of temperature which are characteristic of winter weather. The rise and fall of the dotted temperature belt shows the cyclonic temperature range and corresponds inversely with the pressure changes, *i. e.*, with high pressure (as on February 6 and 10) we find the minimum temperatures, in the early morning, and with low pressure (as on February 8) we find the maximum temperatures, accompanied by a thaw. The rise of temperature in front of the second cyclone (February 11) was moderate, as the winds were northeasterly, the centre being off the New England coast.

easterly or southerly winds in Oregon and Washington. Rain usually begins with southeasterly winds, continuing as the wind veers to south, southwest and west. When, less frequently, the cyclonic centre moves farther south, northerly winds and clear weather prevail over the northern districts. Winds from the northern quadrants are likely to be fair-weather winds at all seasons. The greater the distance of the storm centre, the less is its control over the weather. At San Diego, for example, perhaps less than one-tenth of the storms which cross the northern section of the Pacific coast have any notable effects. California, therefore, has less rain and cloud than prevail in Washington and Oregon, and southern California has even less rain and more sunshine than the northern portion of that State. Well-developed low pressure areas are rare in southern California. When they occur, they cause rains. Occasional lows entering the southwestern portion of the State give light rains along the southern coast, and a subsidiary low over southeastern California ("Sonora storm") may cause rains of relatively large amounts, accompanied by considerable wind movement. On Feb. 24 and 25, 1913, with a low over southern California, occurred the heaviest rainfalls on record at Los Angeles.

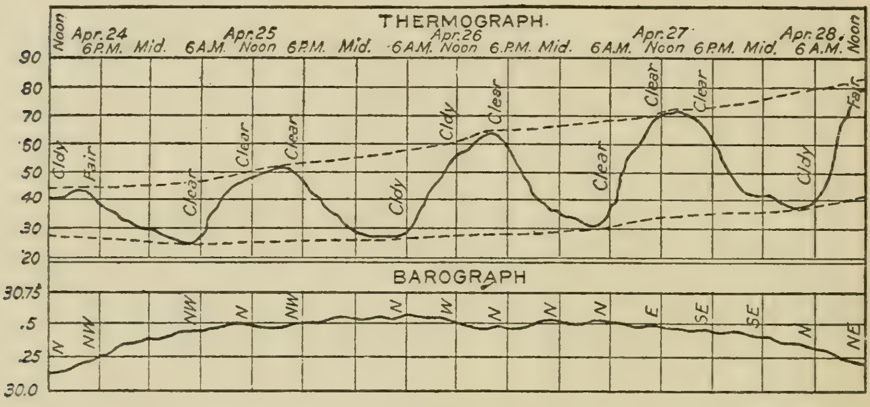

FIG. 33.—Normal diurnal curves, of large range, with a rise in the mean temperature and in the maxima and minima, from day to day under the clear sky of a spring anticyclone. Such conditions give crisp, cool evenings and nights, and bright, warm days. At the beginning of this spell (April 24) the cool wave, with northwesterly winds in front of the approaching anticyclone brought lower temperatures, while the warming increased in the light winds near the centre of the high. The rise in the mean temperature from April 25 to 28 is shown by the rise of the dotted temperature belt. Notice the convex morning, and the concave afternoon curves.

During the winter, the prevailing movement of anticyclones is from the California coast in the vicinity of Cape Mendocino northward to

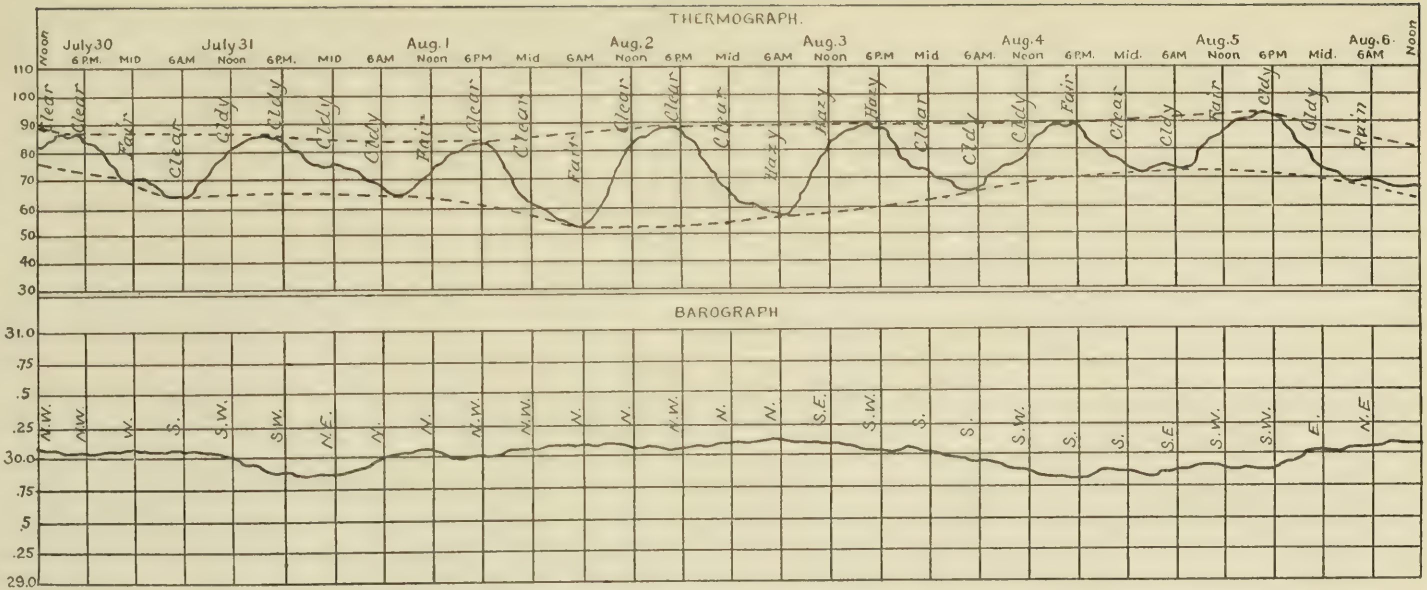

FIG. 34.—Typical summer week of moderate temperatures. The pressure controls are somewhat indefinite and the winds are light and chiefly from the southwest, which is the prevailing summer wind over most of the eastern United States. The diurnal ranges are diminished under clouds (July 31, August 4-5). The minimum temperatures come with cool northerly winds (August 2). The week closes with a narrowing and a fall of the temperature belt, under easterly winds and rain.

about lat. 45° N, crossing northern California and southern Oregon to southern Idaho. There they become stationary, or disappear, or move further east. Other anticyclones come from the north of Montana and move southeasterly toward the Mississippi Valley. When the typical winter low is over the northern Pacific coast, there is usually a high central in Utah, or western Colorado. A marked anticyclone, with low temperatures, fairly stationary north of Montana, and spreading westward towards the coast, retards the eastward movement of the north Pacific coast cyclone. The result may be rain of several days' duration west of the Cascades, and perhaps snow, with freezing temperatures, east of these mountains. If the cyclone is forced southward along the coast, perhaps to the mouth of the Columbia River, and even much further south, there comes a great flow of cold air from the interior, from the north and northeast, which descends the western slopes of the Sierra Nevada and Cascades and comes down into the valleys of Washington, Oregon and California. Heavy snows fall east of the Cascades, as far as Idaho, followed by fair, cold weather over the Pacific coast generally, except on the seaboard. Occasional snows may then fall in western Washington and Oregon, and even on the coast, with northeast winds and low temperatures. With the disappearance of the low to the south, the temperature slowly rises and the snow ceases, but there is no general warming

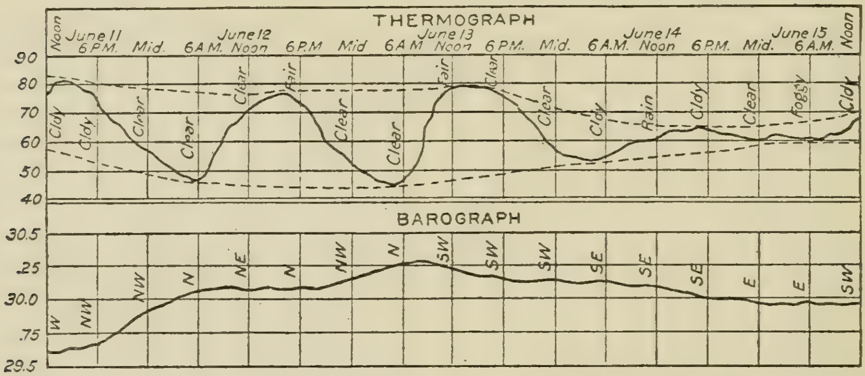

FIG. 35.—Similar conditions to those shown in Fig. 34, but earlier in the season. The maxima are not as high as, and the minima are lower than, those in Fig. 34. On June 14 and 15 there is a marked narrowing of the dotted temperature belt, indicating very small temperature ranges with low maxima, under the rainy and cloudy conditions of these days. The temperature belt is widest under high pressure conditions, the diurnal range being then usually greatest, both in summer and winter (see also Figs. 28, 29, 39), owing to the clear skies with sunshine by day, and the active radiation at night. The temperature belt on June 11 shows a general lowering of the mean temperature in the northwest winds in front of the approaching anticyclone. On June 14, the diurnal maximum is retarded under rain and clouds.

until another cyclone arrives, causing strong winds. These northeasterly winds are the coldest winter winds, but they are of relatively infrequent occurrence.

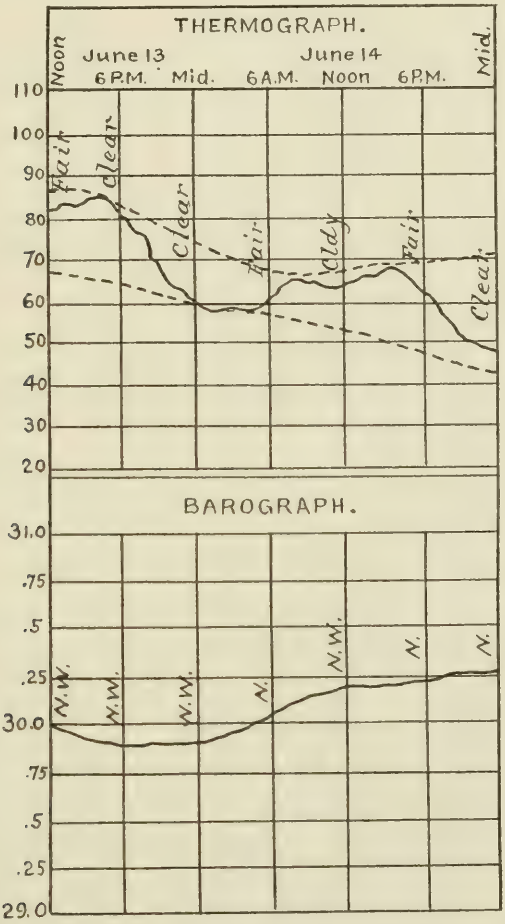

Fig. 36.—Summer cool wave. This temperature curve was recorded during the prevalence of cool northwesterly winds in front of an advancing summer anticyclone. The fall of the temperature belt indicates the general cooling. The cyclonic rise of temperature begins as soon as the northwest winds weaken. The noon maximum is reduced on June 14 by the considerable growth of convectional clouds. Such clouds are a characteristic feature of the fine days which follow our summer rains or thunderstorms. Evaporation is then active under the drying northwest winds, and by noon the sky is often overcast.

Sometimes the low may be forced southeastward over California, bringing general and severe storm conditions in that State, with heavy rains, gales, floods and washouts. An area of high pressure over the northern Pacific coast, or over the Great Basin, with lower pressure in southern California, brings prevailingly clear weather and dry air, except for local rains in the far north; warm days, and relatively cool nights. Under such a distribution of pressure, when the gradient is but moderately steep, "northers" occur in the valleys of California, extending southerly.

There are, of course, many subordinate types of high and low development and movement, each of which has its own characteristic control over the weather. The details of these types it is impossible to consider here. The general character of the winter precipitation on the Pacific Coast obviously depends upon the paths followed by the winter storms. These paths are controlled by the surrounding pressure conditions, and probably also by the movements of the upper air currents. The further south the cyclones move, and the more intense they are, the heavier and the more widespread is the rainfall.

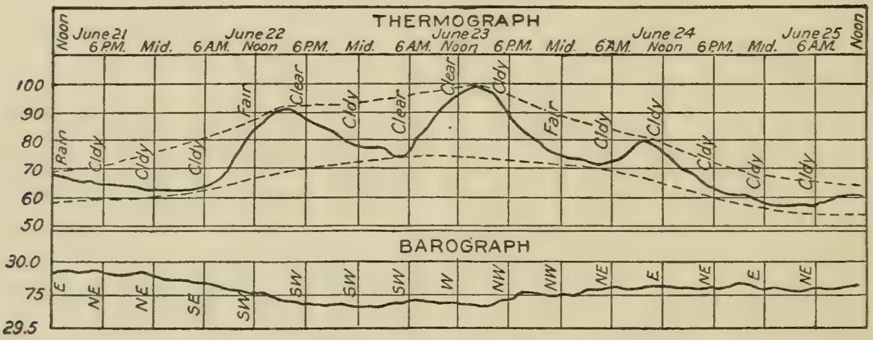

FIG. 37.—Diagram illustrating the contrast between southwesterly and northeasterly winds in New England in summer. Beginning with an even temperature under cloudy skies, easterly winds, and rain, the incoming of sultry southwesterly winds, and fair or clear weather, at once brings a marked diurnal range, with a rise in the temperature belt as a whole under cyclonic control, to a high maximum (June 23). Our highest summer maxima (hot waves) occur under these conditions. Sunstrokes and heat prostrations are then common, and there is much suffering, especially in our large cities. High nocturnal maxima are characteristic of these hot spells. With a shift to northwest winds a general fall in temperature occurs, which is continued under the succeeding east and northeast winds, with small diurnal ranges under cloudy skies, the temperature belt as a whole falling to the right end of the diagram. The low noon maximum on June 25 is due to the cool northeast winds and clouds. Such cool spells afford welcome relief after the high temperatures of a preceding hot wave. The northeast wind is the coolest summer wind on the New England coast.

Summer Weather Types of the Pacific Coast.—From a stormier winter to a drier, more settled, and fairer summer, the change on our Pacific Slope is in general accord with that which takes place the country over. Northward swings the winter storm belt. Northward moves the cyclonic rain belt. The summer cyclones, travelling east along a higher latitude—about that of Sitka—cannot greatly influ-

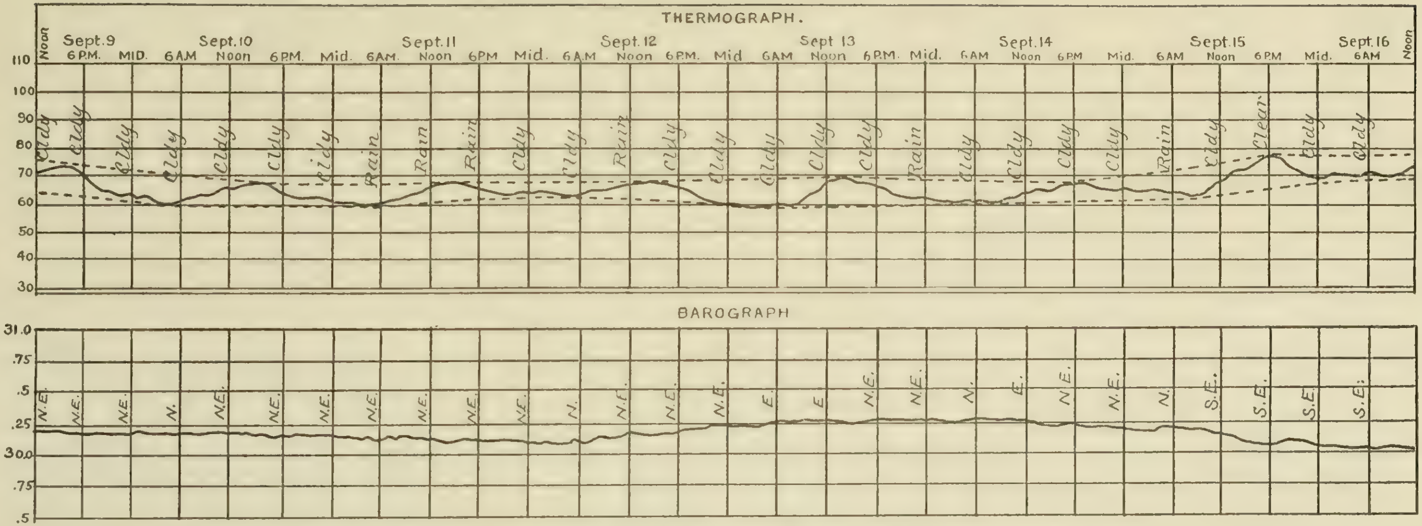

FIG. 38.—A week of clouds and rain in September. A striking illustration of cyclonic control over temperature and weather. The winds are steadily easterly. In consequence, the weather is persistently cloudy, with showers at intervals. The temperature belt shows no cyclonic rise or fall, the pressure control remaining steady. The sun has little direct influence over the temperatures, there being only slight indications of the diurnal range. Such a week as this would tend to confirm the widespread popular belief in an "equinoctial storm." What the curves really do show, however, is the increasing cyclonic control of our weather as summer merges into autumn.

ence Pacific coast weather. They often cause cloudiness without precipitation, but once they have passed beyond the western mountains they are practically negligible, so far as the coast is concerned. The rains diminish as summer approaches. By midsummer, absolute dryness prevails over much of the southern portion of the area. A characteristic of the warmer months is the presence of a more or less enduring anticyclone over the northern or northwestern Pacific coast, while a permanent low extends from the Gulf of California into the Basin region. (Fig. 42.) Hostile to rainfall this pressure distribution certainly is. A summer dry season is the inevitable result. Settled weather, with cool mornings and nights, and warm afternoons; light and local showers, rather than general rains, and even these showers

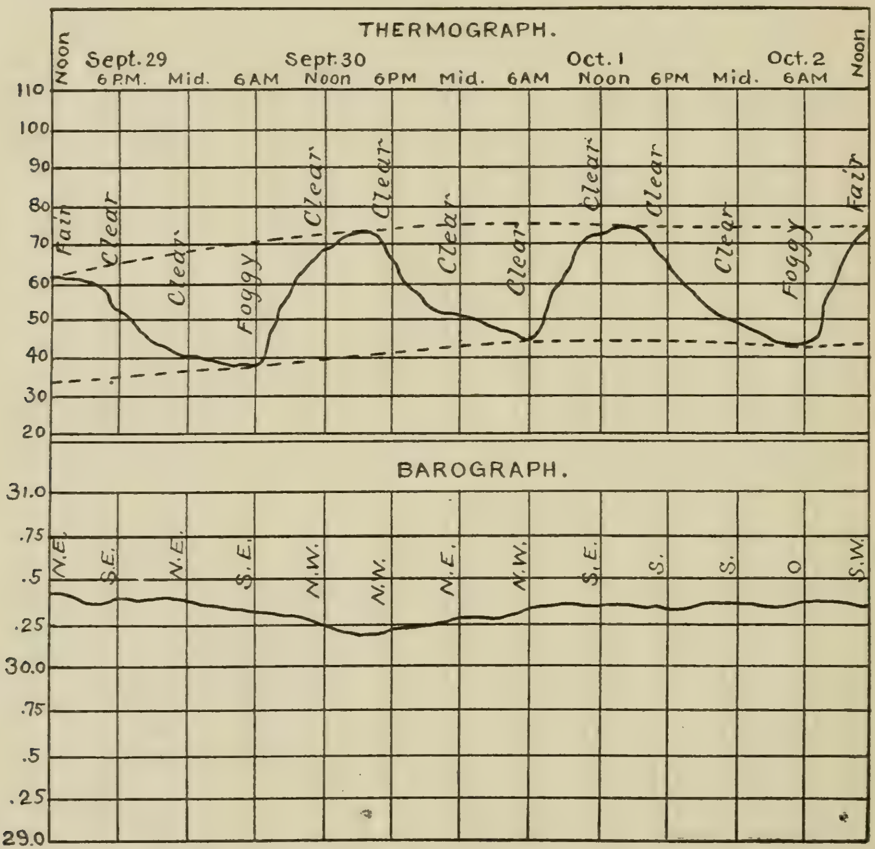

FIG. 39.—Typical fine days in early autumn. Under the light winds and calms of a moderate anticyclone, the diurnal range is well-marked, with warm noons and early afternoons, and crisp, clear nights. The characteristic nocturnal radiation fogs (September 30, October 2) are common in valleys and on lowlands under these conditions. A slightly lower minimum on the night of September 29-30 would have given an autumn frost.

limited to northern sections and to the mountains,—thus we may characterize, in the briefest possible way, the summer of our Pacific Slope. The prolonged rainy and cloudy spells and lower temperatures of winter give way to pleasanter, although occasionally uncomfortably warm, weather types. Yet the high day temperatures under the strong sunshine of the inland sections are accompanied by low relative humidities and the " sensible temperatures " are therefore low. There is a general absence of oppressive muggy heat inland, and the coast temperatures are indeed distinctly cool. Summer showers in northern sections come from lows passing east of the Rocky Mountains whose weather control extends westward, on their rear, or from a weak cyclone which forms over the great valley and afterwards unites with another low over British Columbia. Thunderstorms, of frequent occurrence in eastern Oregon, eastern Washington and Idaho, are rare in

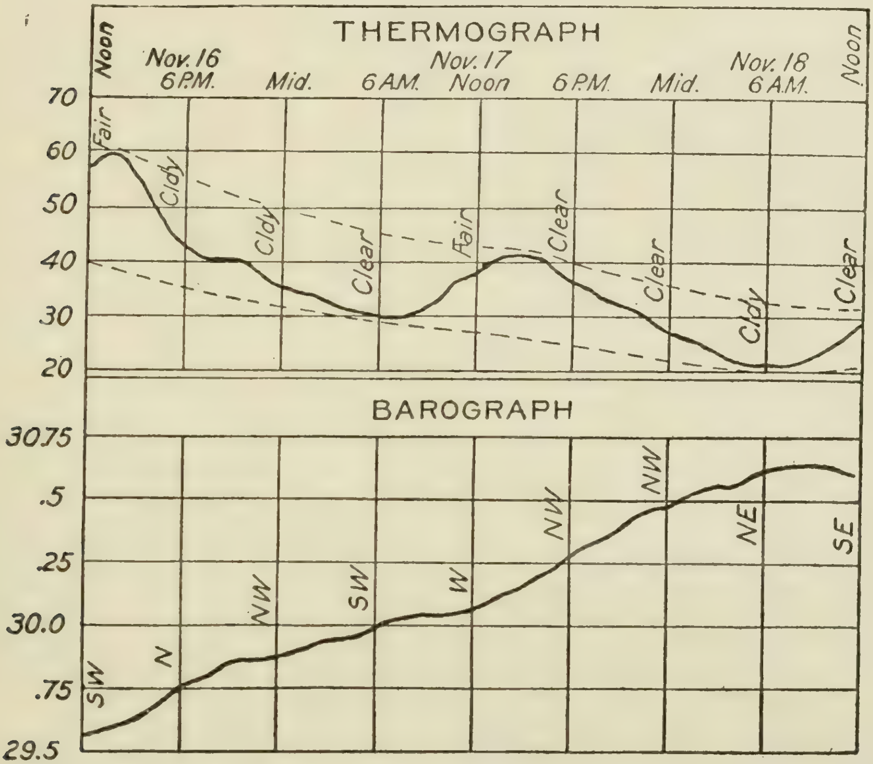

FIG. 40.—An autumn cold wave in front of an approaching anticyclone carries the whole temperature belt down, although the sun is shining, but is unable wholly to extinguish the diurnal range. This illustrates the increasing power of the cyclonic control, which is the great characteristic of winter. The minimum temperature occurs under the maximum pressure, *i. e.*, is the result of local nocturnal radiation.

the western portions of those States, and in California, except in the higher portions of the Sierra Nevada and of the desert. They occasionally occur in summer in the northwestern, western or northern quadrants of a low passing northeast from the central valleys of California to northern Idaho. Fogs along the coast, while high temperatures prevail in the interior, are a notable summer type.

In summer, the characteristic movement of anticyclones is northward along the coast from Cape Mendocino to Vancouver Island (about lat. 50° N), and then easterly, along the same path as that of the winter lows. Moderate anticyclones do not, however, dominate conditions to the eastward, as they seem to break up in the interior. As a high approaches, the north Pacific coast has cooler weather; increasing

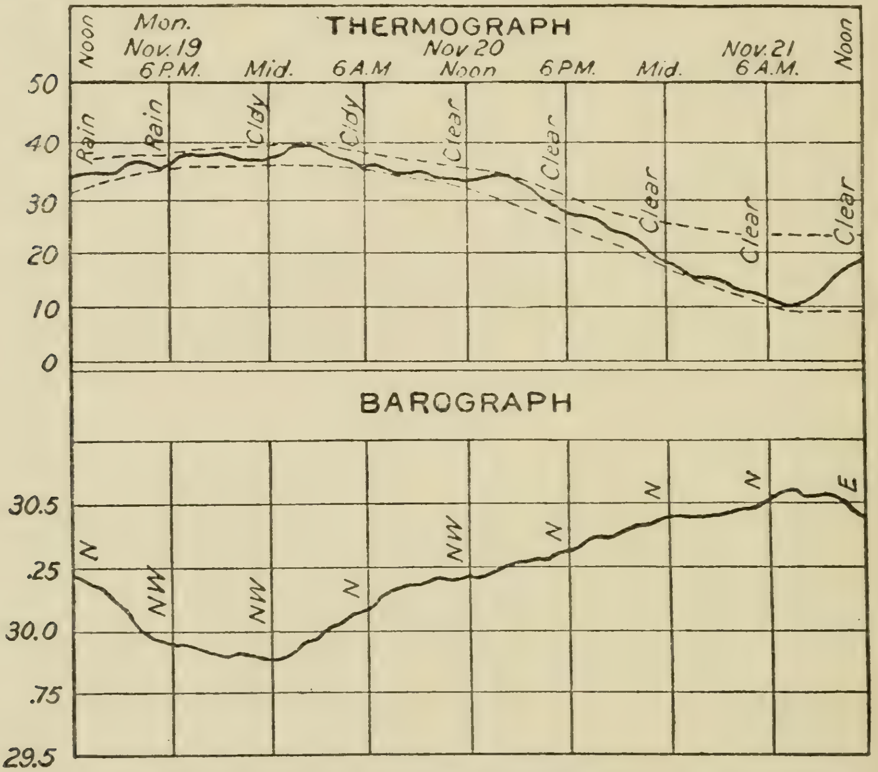

FIG. 41.—November cold spell. After a maximum temperature at night (November 19-20), a fall in temperature, beginning shortly after midnight, continues over noon (November 20), and until early in the morning of the following day. Such a fall of temperature over noon is one of the characteristic signs of approaching winter. The temperature belt is very narrow, showing slight ranges of temperature under the rain and cloudy sky of November 19, and widens under the clear skies and light winds of the anticyclone (November 21). The minimum temperature (November 21) comes under the clear sky of the anticyclonic night, with very light northerly winds.

cloudiness in Washington and Oregon; perhaps showers west of the Cascades. Decreasing cloudiness, and higher temperatures prevail when the centre is north of the mouth of the Columbia River. As the high passes eastward across the Cascades, the sky clears, and the temperature rises, the maximum being recorded when the centre is northeast of Spokane. Hot, dry winds, occasionally injuring crops in Washington and Oregon, may occur under these pressure conditions, the warmest summer winds being north or northeast. When the anticyclone is well-marked over the north, and there is a well-developed low in southern California, hot northerly winds occur in the Sacramento and San Joaquin Valleys. The sequence of weather changes accompanying the progression of a summer anticyclone from the coast of California to beyond the Rocky Mountains usually occupies about five to seven days. When these characteristic summer types of pressure distribution are later than usual, spring is retarded, and farming operations are delayed in northern sections. On the Pacific slope, as elsewhere, there is much weather which is not associated with any very definite cyclonic or anticyclonic conditions. Such types are intermediate, of a more or less nondescript character.

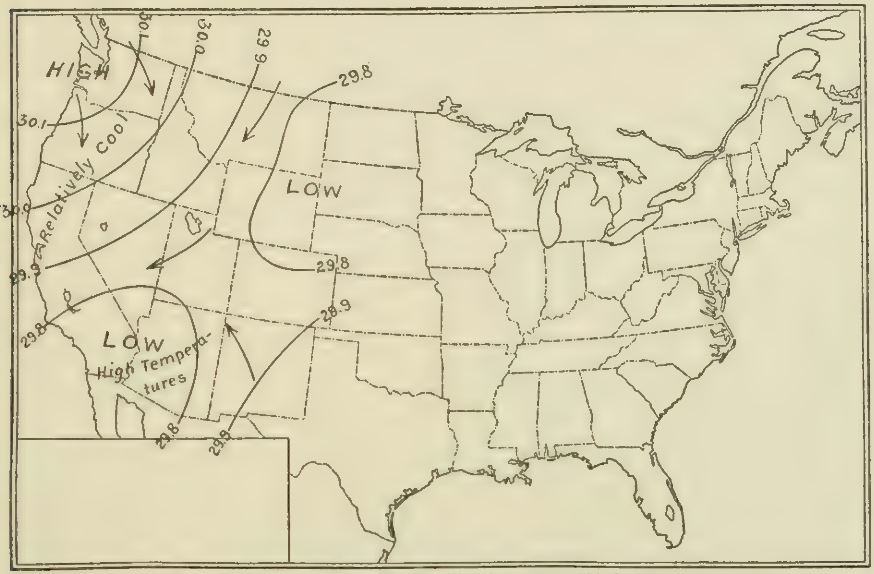

FIG. 42.—North Pacific Summer High.

Winter Weather Types of the Western Interior Province.—The extended region between the Rocky Mountains and the Sierra Nevada-Cascades also has its own individual weather controls and weather types. In winter, especially in December and January, while much of the rest of the country is having unsettled and stormy weather, this western province, together with the Rocky Mountain districts generally, and the Great Plains, may have days and even weeks of fine, cold, dry weather, with generally light winds and marked diurnal variations of temperature, under the control of a persistent, stagnant, anticyclone which stands in the way of storms advancing from the Pacific Ocean, while a series of highs and lows passes along its eastern edge. Snow or rain falls around cyclones of the North Pacific type following the northern circuit across the Columbia Plateau, or in connection with those which cross the central or southern parts of the district on their eastward journey. The former being the more numerous, the northern portion of this province has heavier precipitation than the southern. The total precipitation which falls from such storms is, however, generally light, as the rain-shadow effect of the Pacific coast mountains, and the generally effective enclosure of the whole province would lead us to expect. The inflowing air currents lack the plentiful supply of water vapor which is characteristic of cyclonic circulation in the east, or on the northern Pacific coast. General cloudiness, rains, or snows, over the southern portion of the interior province come in connection with a cyclone which covers that district and is delayed in its eastward progress across the Rocky Mountains (Fig. 9). The area of clouds and of precipitation may also include the central and southern Rocky Mountain region. Cold waves are less frequent and less severe than over the region east of the Rocky Mountain barrier. In the north, they occur under well-marked anticyclonic controls, and are associated with northeasterly and northerly rather than with northwesterly winds, as is the case in eastern sections. In the middle and southern plateau regions they occur in the wake of deep low pressure areas moving across the Rocky Mountains, and are attended by high southwest to west winds. Cold, much below that common to the latitude, is generally developed. A low passing across the southern part of the Great Basin region followed by a high which moves southward over Idaho and Utah may bring killing frosts as far south as southern Arizona. The conditions of falling temperature move from north to south, often very rapidly, and may extend from the Pacific coast across the Rocky Mountains. When this air drainage is marked, the freezing line may extend as far south as the citrus region of California, as in the winter of 1913. High winds are common, and occur in winter and spring on steep cyclonic gradients.

Summer Weather Types of the Western Interior Province.—In place of the characteristic, more or less permanent winter anticyclone, the summer conditions over the Plateau and Basin province are marked by the presence of a fairly permanent and ill-defined low over the lower Colorado region,—the so-called Yuma low. Anticyclones from the northwest temporarily interfere with this cyclonic control, and tend to emphasize the effect of this low, but the latter reestablishes itself as the highs move eastward. In fact, it is a sign of spring when the winter Rocky Mountain high pressure area weakens, and the low from the Gulf of California establishes itself. Summer weather over this great interior province is characteristically fine, and settled. Day after day the same uniform conditions prevail, especially in the southern section. Temperatures are high, especially in the south and at lower levels, but the greater elevations enjoy cooler nights, although the days are hot. The strong diurnal ranges of temperature, characteristic of this mountain and plateau country, with its prevailingly bright sunshine and dry air, may easily bring frost on the higher elevations during the clear nights of spring and early summer. Rainfall is generally light, the summer cyclones being weak and ineffective as rain-bearers. In the south, over southeastern California, Arizona, southern Utah and southern Nevada there is a more or less marked summer maximum, known locally as the " rainy season," and usually beginning early in July. These rains are essentially local thunderstorm rains, although they occur in connection with the general cyclonic trough of low pressure. Thunderstorms in Idaho come with the advance of low pressure areas from the northern interior of California.

Winter and Summer Weather Types of the Great Plains.—The Great Plains share to some extent in the weather types of the two regions which join them on the east and on the west. The great permanent winter anticyclone, west of the Continental Divide, referred to in a previous paragraph, extends its influence over the Great Plains area, giving much clear and settled winter weather. The temperatures east of the Divide, in the western Great Plains area, are usually mild under this anticyclonic control, with a succession of relatively dry, warm and bright sunny days, the prevailing winds being westerly, across the Continental Divide. At the same time it is intensely cold to the west of the mountains in the region dominated by the high. But the procession of winter cyclones keeps marching across the Plains chiefly in the north, and cold waves, gales, snows and blizzards sweep over the area. Sometimes the cyclones loop far south and severe conditions reach into New Mexico and Texas, damaging southern crops, and causing losses of cattle. Some of the most important storms of the Great Central Valley and the eastern United States originate in the Southwest and cross the Continental Divide in New Mexico. Sometimes the pressure barrier in the Rocky Mountain region is such that the Divide is crossed in Mexico. The storms then generally move northeastward. These lows give to the Plains region heavy snows, and with the eastward movement of the cyclone cold air from the Canadian

Northwest sweeps southward along the eastern side of the Continental Divide. "Colorado type" storms may bring general cloudiness and precipitation over much of the Great Plains district (Figs. 16, 17). In summer, the Plains share with the rest of the country long spells of settled diurnal weather; with hot waves and drought not infrequently extending over many days, or even weeks; with thunderstorms bringing local temporary relief, and with occasional general storms bringing more widely distributed and beneficial rains. Easterly winds, climbing the mountain slopes toward the lower pressure areas of the interior province, give summer precipitation over the mountains to the west of the Plains. Well defined cyclonic areas are not common over the central and southern Great Plains, and comparatively few cross the Continental Divide in the southern United States. Weak low pressure areas which succeed in reaching the eastern slope usually move northeast, developing as they travel eastward.

The foregoing description and illustration of some of our more important seasonal and regional weather types is manifestly incomplete and superficial. It is only by means of a careful examination of the daily weather maps, season by season, and year by year, that the student of the climatology of the United States can really make himself thoroughly familiar with these types. The suggestions here made will aid in such a detailed investigation.

NOTE.—In Figs. 5-24 the light shading indicates cloudiness; the heavy shading shows areas of precipitation.

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THE SUBDIVISION OF NORTH AMERICA INTO NATURAL REGIONS: A PRELIMINARY INQUIRY

WOLFGANG L. G. JOERG

CONTENTS

Page
Natural Region the Unit of Investigation in Modern Regional Geography. 55
Definition and Constituent Elements of a Natural Region............... 55
Methods to be Followed in Establishing Natural Regions................ 58
Survey of Previous Classifications of North America and the United States (maps, Figs. 1-21).. 59
Selective Classification Based on the Preceding....................... 61
Conclusion.. 61
Illustrative Figures 62

NATURAL REGION THE UNIT OF INVESTIGATION IN MODERN REGIONAL GEOGRAPHY.—With the recognition of regional geography as the ultimate goal and highest expression of geographical research, which has come with the modern development of our science, there has been a marked increase in the attention devoted to this branch of the subject and to its methods. One of the most important questions of method is that which refers to the unit of investigation. Economy of presentation and sound geographical reasoning both demand that such units be as homogeneous as possible. Inasmuch as this requirement is but rarely fulfilled by artificial units, such as political divisions, and as geographical phenomena appertain to the physical world, modern workers have urged and practiced the use of natural regions as the fundamental units of geographical investigation. The French school, for instance, whose efforts have mainly been directed towards a systematic treatment of France, has adopted this method. Vidal de la Blache, the dean of French geographers, himself uses it in his *La France: Tableau géographique,* and a natural region of France forms the subject of each of the various monographs prepared as doctors' theses at the Sorbonne. Among German examples of this method Partsch's *Mitteleuropa,* Philippson's *Europa* and *Das Mittelmeergebiet,* Passarge's *Südafrika* and Fischer's *Südeuropäische Halbinseln* may be cited among many others. It therefore seems fitting to examine what attempts have been made to apply this method to North America with a view to determining, if possible, what are the natural regions of this, the continent which interests us most.

DEFINITION AND CONSTITUENT ELEMENTS OF A NATURAL REGION.—Before doing so, however, it will be advisable to inquire into what constitutes a natural region and what methods should be followed in delimiting provinces of this type The comprehensiveness of this topic and the restrictions of space will only allow brief reference to the most salient points. In this inquiry the investigations of Herbertson,[1] Hettner,[2] Gallois,[3] and Passarge[4] will prove helpful. Herbertson's paper, which was the first to broach the subject, culminates in a subdivision of the earth into natural regions; Hettner and Gallois discuss mainly the principles of subdivision; while Passarge subdivides Africa on the basis of a systematic review of all the elements involved. In this country, Dryer[5] has recently devoted attention to the subject.

A natural region may be defined as any portion of the earth's surface whose physical conditions are homogeneous. The term is as applicable to the water as to the land surface of the globe, as Schott has recently shown in his admirable *Geographie des Atlantischen Ozeans.* For the purposes of the present inquiry, however, it will be restricted to the land surface. In this sense, then, what elements compose a natural region? The following, it is suggested, may be enumerated: (1) structure and relief; (2) climate; and (3) vegetation. At first thought it might seem as if all the elements involved in a systematic regional treatment would come into consideration, viz., in addition to those just mentioned, zoögeography and anthropogeography. But reflection will show that anthropogeographic factors are not suitable criteria. Natural regions may be said to represent environmental types: it would obviously be confusing cause and consequence to apply the phenomena of human geography in their definition. Even such non-artificial units as economic and cultural regions,[6] as Gallois points out, do not come into consideration, for, while they reflect environment, they do not constitute it. This exclusion of the human element does not imply any disparagement of anthropogeography. On the contrary, man's activities will be interpreted all the better the more clearly his environment is recognized. In fact, it may be said that the recognition of the desirability of subdividing the earth's surface into natural regions is a direct consequence of the development of regional anthropogeography.

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[1] A. J. Herbertson; The Major Natural Regions: An Essay in Systematic Geography, *Geogr. Journ.*, Vol. 25, 1905, pp. 300-312; one phase established in: The Thermal Regions of the World, *Geogr. Journ.*, Vol. 40, 1912, pp. 518-532. See also *idem:* Discussion on Natural Regions of the World, *Report Brit. Assoc. Adv. Sci., Birmingham meeting, 1913*, pp. 557-559, summarized in *Geogr. Journ.*, Vol. 42, 1913, pp. 474-476.

[2] A. Hettner: Die geographische Einteilung der Erdoberfläche, *Geogr. Zeitschr.*, Vol. 14, 1908, pp. 1-13, 94-110 and 137-150.

[3] L. Gallois: Régions Naturelles et Noms de Pays: Étude sur la Région Parisienne (especially Chapters I and XII), 1908.

[4] S. Passarge: Die natürlichen Landschaften Afrikas, *Petermanns Mitt.*, Vol. 54, 1908, pp. 147-160 and 182-188, with seven maps, 1:60,000,000, showing the geology, relief, geomorphology, drainage basins, vegetation, natural regions, and economic provinces.

[5] C. R. Dryer: Regional Geography, *Journ. of Geogr.*, Vol. 11, 1912-13, pp. 73-75, and High School Geography, 1912, pp. 328-339. See also second reference under Fig. 16.

[6] On the relation of economic to natural regions see P. M. Roxby: What is a "Natural Region,"?, *Geogr. Teacher*, Vol. 4, 1907-08, pp. 123-128.

With regard to zoögeography, the other element mentioned, the same objection holds good. For, although faunal life is broadly dependent on habitat, it does not reflect environment as faithfully as does vegetation, for instance, due to the mobility of the one and the fixity of the other.

There remain the three elements, relief, climate, and vegetation. Of these, only relief and climate are coordinate. These two are the fundamental factors; from their interaction the majority of geographical phenomena result. Such is the case with vegetation, for instance. Although only a resultant, its importance as a criterion in the delimitation of natural regions lies in the fact that it affords a very delicate index of climate. Its predominance in the landscape also insures its consideration in any scheme of this nature.

The question as to what phases should be considered of each element involved is not unimportant. Relief should, of course, be correlated with structure. In this connection, the broad structural divisions, such as folded mountains, unfolded lowlands and tablelands, etc., are the most useful. Of the climatic elements, temperature and rainfall are the most important, and the seasonal distribution of both is at least of equal consequence to the amount. Under vegetation the phytogeographical regions and not the flora would, of course, afford the proper basis.

Another pertinent matter is the question of the rank, or order of size, of a natural region.[7] This will obviously depend on the degree of subdivision applied and this, in turn, on the size of the unit subdivided. The major natural regions into which the world or a continent may be divided are capable of further subdivision into minor natural regions. Thus the Paris Basin and Brittany form part of the major Western Marginal Lowland province of Europe. Nevertheless, an ideal degree of subdivision is conceivable which would bear a definite relation to the size and complexity of the unit to be subdivided and would insure the recognition of every homogeneous region. In the case of minor regions other criteria, such as soil, for instance, may be necessary in addition to those already enumerated in order to do justice to their more delicate organization.

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[7] In the discussion which followed the reading of this paper at the Princeton meeting of the Association it was pointed out that compactness should be aimed at in establishing natural regions. Proper generalization will insure attaining this important attribute. Thus, the Little Belt and Crazy Mountains of Montana would be included in the Rocky Mountain System, while the Black Hills would be retained as a distinct unit, due to their characteristic isolation in the Great Plains. It is the lack of compactness in many vegetational and other maps which consider the altitudinal effect of climate, with their resultant "islands" or "enclaves" (cf. Figs. 12, 14, 15), which militates against their direct use as bases for maps of natural regions.

METHODS TO BE FOLLOWED IN ESTABLISHING NATURAL REGIONS.—If we now turn to the methods which may be followed in establishing a subdivision into natural regions we find that two are possible: the inductive and the deductive. The inductive first visualizes the individual regions and then groups them together into larger units; the deductive starts with the larger unit and subdivides it into its various parts. The former is the method of direct observation in the field, the latter that of systematic description. From his travels in Venezuela Humboldt arrived at the conception of the llanos; from a survey of world geography Herbertson deduced his natural regions. The inductive method is necessarily the first to be followed, but when our knowledge of a certain region has progressed sufficiently the deductive method is legitimate.

With regard to the question as to what principle of classification should be applied in order to delimit the natural regions of a certain area, it is obvious that not only one, but a combination of all the critical elements—structure and relief, climate, vegetation—should be used. One element may predominate over the other; the problem is precisely to evaluate their relative importance. Structure and relief, for instance, will be the guiding principle in the delimitation of the Cordillera; low rainfall, in that of the Great Plains. Furthermore, the selection of the predominating element may be prescribed by the rank of the unit to be subdivided, as previously suggested. This change of emphasis may lead to a lack of coincidence between a major region and the minor regions which constitute it, as, for instance, if a mountain range be considered the limit between two major regions and the range a minor region by itself.

These difficulties give us a clue as to the value of all such classifications. Some systematists have believed that a definite scheme of subdivision exists in nature, and that it is only necessary to determine it. Definite divisions, however, only exist in each of the constituent elements, i. e., there are definite areas of young folded mountains or of savanna. The classifications according to the different categories cross each other; none is the sole determinant. The geographer must choose among them, and this choice depends on his evaluation of their relative importance. Such evaluations are, of course, subjective. For this reason it is not a question of whether a given subdivision is right or wrong, as Hettner points out, but only whether it is expedient or not. Hence the helpfulness of reviewing previous classifications of the natural regions of a given area with a view to judging which does most justice to the natural conditions as defined above.

SURVEY OF PREVIOUS CLASSIFICATIONS OF NORTH AMERICA AND THE UNITED STATES.—In the accompanying figures (Figs. 1-21) the attempt is made to present the most important classifications of this nature that relate to North America or the United States, as the case may be. Each constituent element of a natural region is represented by several examples, and there are six subdivisions which aim to delineate the natural regions themselves. These classifications, designated by their authors and the date of their first publication, and arranged according to categories, proceeding within each from the simpler to the more complex, are as follows:

Structural
- Blackwelder (orographic), 1912
- Blackwelder (physiographic), 1912
- Gannett, 1902
- Davis, 1899
- Tarr and von Engeln, 1913
- Bowman, 1911
- Dryer, 1912
- Powell, 1896, and Brooks, 1906

Climatic[8]
- Supan, 1903
- Hult, 1893
- De Martonne, 1909
- Köppen, 1900

Vegetational[9]
- Hardy, 1909
- Harshberger, 1911

Zoögeographic[9]
- Merriam, 1910

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[8] For a survey of previous classifications of this nature, including those here mentioned, except De Martonne, see R. DeC. Ward: The Classification of Climates, *Bull. Amer. Geogr. Soc.*, Vol. 38, 1906, pp. 401-412 and 465-477, and Chapters II and III of: Climate, Considered Especially in Relation to Man, 1908. See also *idem:* A Note on the Classification of Climates, *Bull. Amer. Geogr. Soc.*, Vol. 46, 1914, pp. 108-116.

[9] In the domain of phytogeography and zoögeography attention should also be called to the classifications presented in the following:

O. Drude: Handbuch der Pflanzengeographie, 1890.

A. F. W. Schimper: Pflanzengeographie auf physiologischer Grundlage, 1898.

A. Engler: Die pflanzengeographische Gliederung Nordamerikas, *Notizblatt des königl. botan. Gartens (Dahlem-Steglitz)*, Appendix IX, 1902.

B. E. Livingston: Climatic Areas of the United States as Related to Plant Growth, *Proc. Amer. Philosoph. Soc.*, Vol. 52, pp. 257-275.

J. A. Allen: The Geographical Distribution of North American Mammals, *Bull. Amer. Mus. Nat. Hist.*, Vol. 4, 1892, pp. 199-243.

Natural Regions[10]

- Dryer, 1912
- Banse, 1912
- Fischer and Geistbeck, 1912
- Herbertson, 1905
- Unstead and Taylor, 1910
- Sievers and Deckert, 1907

The originals of these maps are on various projections and scales. In order to establish a uniform standard of comparison, they are here presented on the same projection and—for each of the two areas shown—on the same scale. It was desired to reproduce the maps both of the United States and of North America on the same scale; but it proved impracticable to do so. Even so, the main advantage of identity of scale is not lost: the more minute degree of subdivision applied to the United States, as compared with North America, is visible at a glance. This difference is natural, inasmuch as only a part of the continent has been the unit in the one case as against the whole in the other. However, this comparison in itself may be helpful in suggesting to what degree of subdivision to proceed in order to attain the ideal referred to previously. The scale of the United States maps is about 1:50,000,000; of the maps of North America, about 1:85,000,000. As regards projection, many of the original maps are world maps on Mollweide's projection. As the central meridian used is generally that of Greenwich, North America is pushed to the edge of the map, and considerable distortion results, especially in the northwest, where Alaska is most affected. The advantage of centering the image of the continent, as is done here, is obvious: but, for the reason given, the regional boundaries in the northwest may not always strictly reproduce the author's intent.

Space forbids a critical analysis of the classifications shown on the accompanying figures. Its place must, to a certain extent, be taken by the appended synopses, which are intended not only to furnish a key to the symbols used but also to correlate the various subdivisions shown. In some cases where the original map furnished no clue, correlation has been attempted on the basis of the author's text. Where possible, the author's notation has been used; where not, Arabic numerals have been employed to denote major divisions, small letters to designate their subdivisions, and subscripts to indicate divisions subordinate to these. In general, areas not subdivisions of the unit in which they occur and extraneous to it have been indicated by a capital letter with the number of the region in which they lie as a subscript, as, for instance, the Black Hills in the Great Plains region (Fig. 4), B_9. Divisions enclosed in brackets in the synopses do not form part of North America (here conceived to be bounded by Denmark and Bering Straits and the Isthmus of Panama.)

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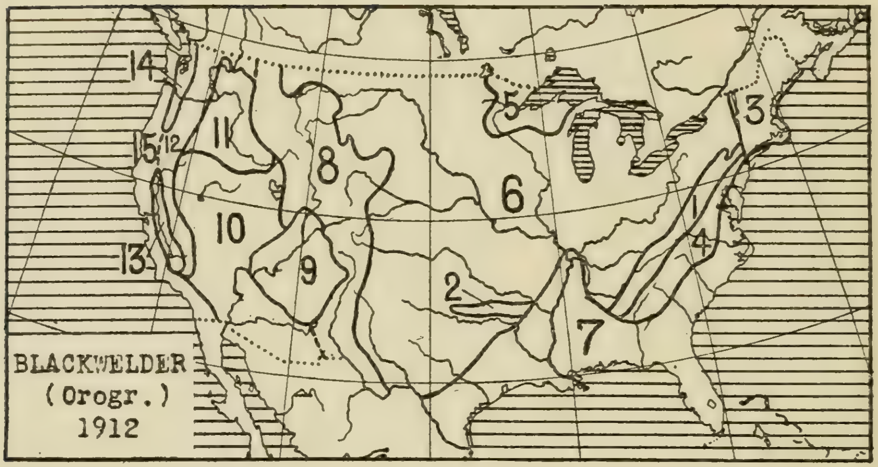
[10] See also the maps of the natural regions of the United States, 1:23,000,000, and of Canada, 1:23,000,000, in J. McFarlane's recent Economic Geography, which it was impossible to include here.

Selective Classification Based on the Preceding.—While a discussion of the various classifications is not possible, a selection of their best features may be helpful. This the writer has attempted to do in Figure 22. The regions shown on it are based on a study of the previous classifications and a selection of what seems best in them. Such a method, it need not be said, is not the best; only an intensive study of the various phases of the geography of the continent, as that undertaken by Passarge for Africa, can afford a proper basis for such an endeavor. The present classification lays no claim to such a foundation. Nevertheless, even a classification at second hand may have some value, provided the sources are well chosen.

However, to add another to the already existing classifications may seem mere supererogation. This would be the case were not the object of each classification its own justification. For the purpose for which it is intended, probably no scheme here referred to is as satisfactory as that by Herbertson. Its object—as of the other classifications comprising the whole world—is to correlate the various regions of the world, to match like with like, and in this it admirably succeeds. No end could be more worthy, for the comparative regional geography of the world as a whole may well be considered the highest goal of our science. But the description of smaller units is also a legitimate object; and it was with a view to establishing a classification which might serve as a basis for a systematic regional treatment of North America, that the present inquiry was undertaken. A subdivision of this nature, to satisfy the ideal requirement of adequate detail already referred to, may well have to be more minute than one which aims only at broad generalizations.

Conclusion.—In conclusion it is desired to emphasize the tentative nature of this investigation. The principles governing the establishment of natural regions have been briefly discussed, the main classifications of this nature for North America have been reviewed, and a selective classification deduced from them. But no attempt has been made to do the constructive work of establishing the natural regions of North America on the basis of an intensive study of its geography. It has been the intention rather to pose the problem than to solve it.


14
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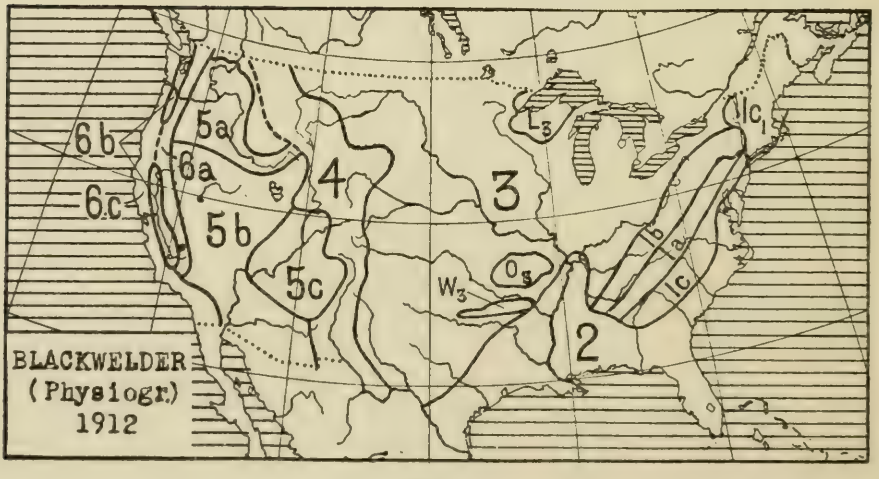
BLACKWELDER
(Orogr.)
1912

FIG. 1.


6b
5a
6a
6c
5b
4
5c
3
L3
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O3
2
1c1
1b
a
1c
BLACKWELDER
(Physiogr)
1912

FIG. 2.

FIG. 1.—From E. Blackwelder: United States of North America (Handbuch der regionalen Geologie, edited by Steinmann and Wilckens, Vol. 8, Part 2, 1912), Fig. 4, Orographic Elements of the United States, 1:40,000,000.

1 Appalachian element
2 Ouachita element
3 New England element
4 Piedmont element
5 Lake Superior element
6 Interior Lowlands element
7 (Atlantic and Gulf) Coastal Plain
8 Rocky Mountains element
9 Colorado Plateaus
10 Basin Ranges element
11 Columbia Lava Plateau
12 Sierra Nevada and Cascade Mountains element
13 California Valley
14 Puget Trough
15 Coast Ranges

FIG. 2.—From E. Blackwelder: *ibid.*, Fig. 1, Physiographic Provinces of the United States, 1:40,000,000.

1 Eastern Highlands
    1a Appalachian Mountains
    1b Appalachian Plateau
    1c Piedmont Plateau (*or* Region)
        $1c_1$ New England Plateau
2 Coastal Plain
3 Interior Plains
    L_3 Lake Superior Highlands
    O_3 Ozark Plateau
    W_3 Ouachita Mountains
4 Rocky Mountains
5 (Intermontane Plateaus and Ranges)
    5a Columbia Plateau } Basin Plateaus
    5b Basin Ranges }
    5c Colorado Plateaus
6 Pacific Mountains
    6a Cascade Mountains-Sierra Nevada
    6b (Puget Sound-Willamette Depression) and California Valley
    6c Coast Ranges

Terms in parentheses are used or implied in the text; the correlations are not explicitly given, but are deduced from the text.

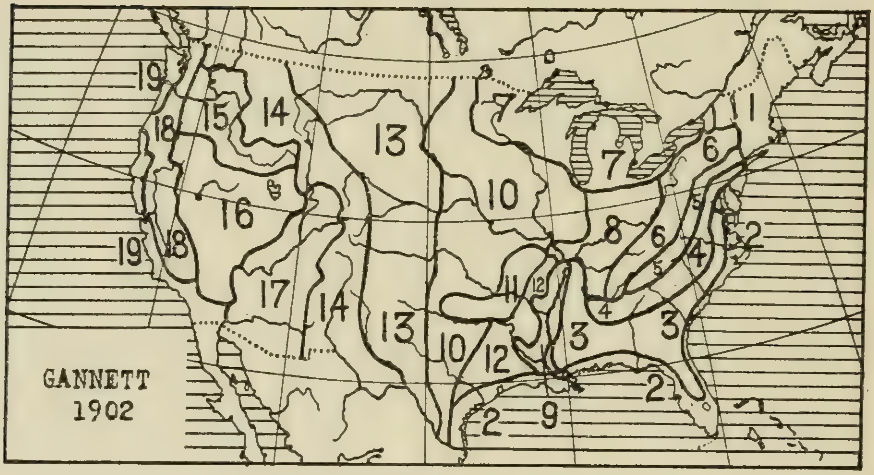
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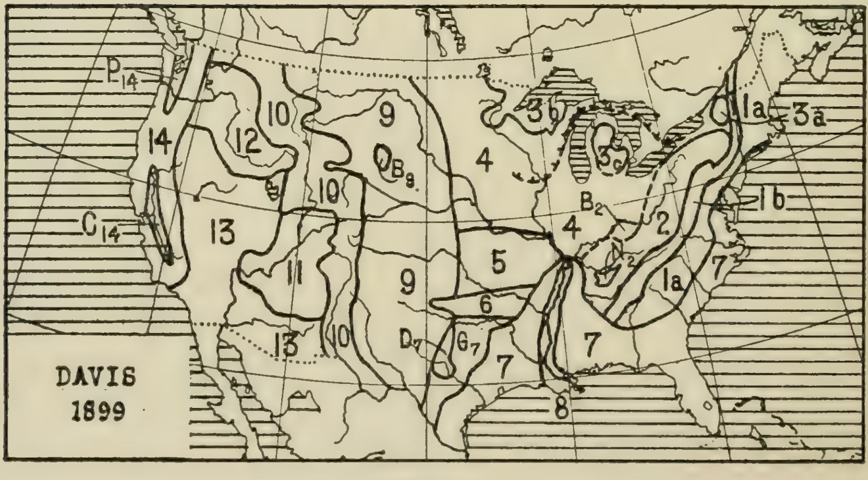
Fig. 3.


P_{14}
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3b
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B_8
3_c
B_2
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9
6
1a
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13
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D_7
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8
DAVIS
1899

Fig. 4.

FIG. 3.—From W. F. Willcox: A Discussion of Area and Population [of the United States], *12th Census of the United States, Bull. No. 149*, 1902, map (by H. Gannett), p. 10, 1:27,000,000. Reproduced in [*Permanent*] *Bureau of the Census Bull. 1*, 1903, and A. Supan: Die Bevölkerung der Erde, XII (*Ergänzungsheft No. 146 zu Petermanns Mitt.*, 1904).

1 New England hills
2 Coast lowlands
3 Coastal plain (east of the Mississippi River)
4 Piedmont region
5 Appalachian valley
6 Allegheny plateau
7 Lake region
8 Interior timbered region
9 Mississippi alluvial region
10 Prairie region
11 Ozark hills
12 Coastal plain (west of the Mississippi River)
13 Great plains
14 Rocky Mountains
15 Columbian mesas
16 Great basin
17 Plateau region
18 Pacific valley
19 Coast ranges

On the original map the boundaries shown follow the county boundaries which most closely approximate the natural boundaries. This is done in order to apply the statistics for population directly to the natural divisions. On the accompanying figure the resulting irregularities in the natural boundaries have been smoothed out.

FIG. 4.—From W. M. Davis: The United States of America (in: The International Geography, edited by H. R. Mill, 1909), Fig. 353, The Physical Divisions of the United States, 1:30,000,000.

1 Appalachian Belt
    1a Older Appalachian Belt
    1b Newer Appalachian Belt
2 Allegheny Plateau
    B_2 Blue Grass Region
    N_2 Nashville Basin
3 Outliers of Laurentian Highlands
    3a Adirondacks
    3b Wisconsin-Michigan Uplands
    3c Michigan Upland
4 Prairies (divided by Niagara Escarpment)
5 Ozark Plateau
6 Ouachita Mountains
7 Coastal Plains
    G_7 Grand Prairie
    D_7 "central denuded region"
8 Mississippi Flood Plain
9 Great Plains
    B_9 Black Hills
10 Rocky Mountains
11 Colorado Plateaus
12 Columbia Plateaus
13 Basin Ranges
14 Pacific Ranges
    C_{14} Valley of California
    P_{14} Puget Sound Valley

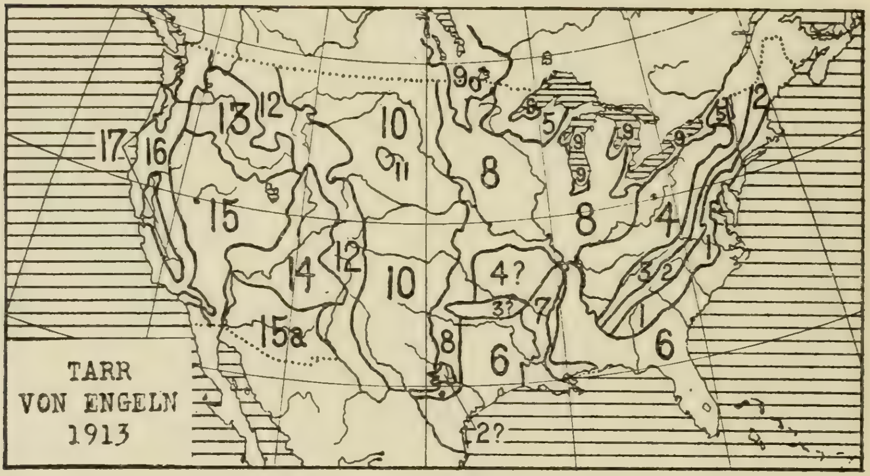
TARR
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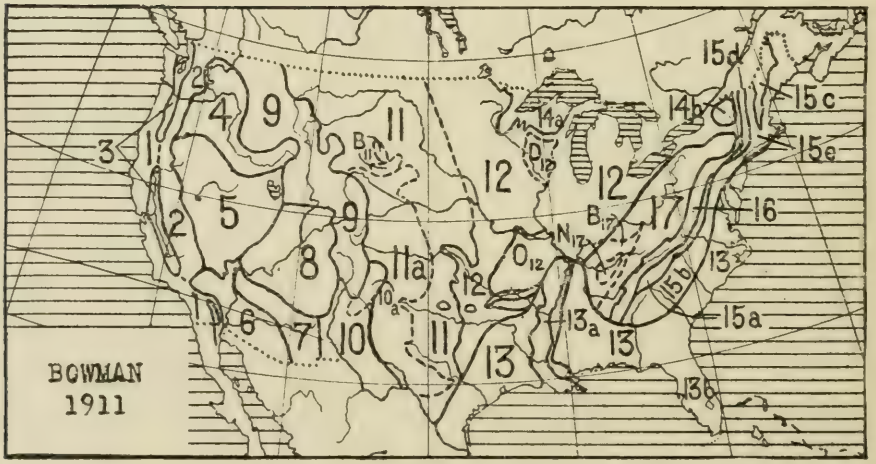
Fig. 5.


BOWMAN
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B11
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14b
15c
15e
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2
9
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11a
12
O12
N17
B17
17
13
15b
15a
10a
1
6
7
10
11
13
13a
13
13b

Fig. 6.

Fig. 5.—From R. S. Tarr and O. D. von Engeln: A Laboratory Manual for Physical and Commercial Geography, 1913, frontispiece (map of the physiographic provinces of the United States, 1:25,000,000).

1 Appalachian Piedmont
2 Crystalline Appalachians
3 Folded Appalachians
4 Appalachian Plateau
5 Laurentian Highlands
6 Coastal Plains
7 Mississippi Flood Plain and Delta
8 Central Plains
9 Glacial Lake Plains
10 Great Plains
11 Black Hills
12 Rocky Mountains
13 Columbia Lava Plateau
14 Colorado Plateau
15 Great Basin
    15a Open Basins
16 Pacific Ranges
17 Piedmont Valleys of the Pacific Slope

Fig. 6.—From I. Bowman: Forest Physiography (Physiography of the United States, etc.), 1911, Pl. IV, Physiographic Provinces of the United States, 1:15,000,000.

1 Coast Ranges
2 Cascade and Sierra Nevada Mountains
3 Pacific Coast Valleys
4 Columbia Plateaus and Blue Mountains
5 Great Basin
6 Lower Colorado Basin
7 Arizona Highlands
8 Colorado Plateaus
9 Rocky Mountains
10 Trans-Pecos Highlands
    10a Mesa de Maya, Ocate and Las Vegas Mesas
11 Great Plains
    11a High Plains
    $B_{11}\left\{\begin{array}{l}\text{Black Hills}\\ \text{Bad Lands}\end{array}\right.$
12 Prairie Plains
    D_{12} Driftless Area
    O_{12} Ozark Highlands
13 Atlantic and Gulf Coastal Plain
    13a Lower Alluvial Valley of the Mississippi
    (13b Florida)
14 Laurentian Plateau and Outliers
    14a Superior Highlands
    14b Adirondack Mountains
15 Older Appalachians
    Southern
        15a Appalachian Mountains
        15b Piedmont Plateau
    Northern (= New England)
        15c White Mountains and bordering uplands
        15d Green Mountains and bordering uplands
        15e Connecticut Valley
16 Newer Appalachians
17 Appalachian Plateaus
    $\left.\begin{array}{l}B_{17}\text{ Blue Grass Country}\\ N_{17}\text{ Nashville Basin}\end{array}\right\}$ local lowlands

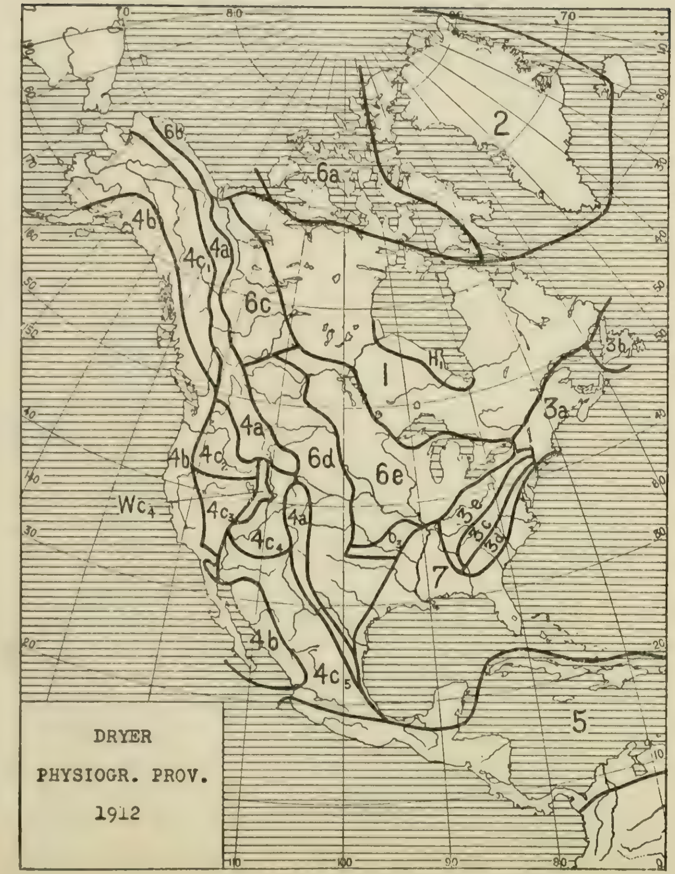
DRYER
PHYSIOGR. PROV.
1912
2
6a
6b
6c
6d
6e
1
3a
3b
3c
3d
3e
4a
4b
4c1
4c2
4c3
4c4
4c5
Wc4
5
7

FIG. 7.

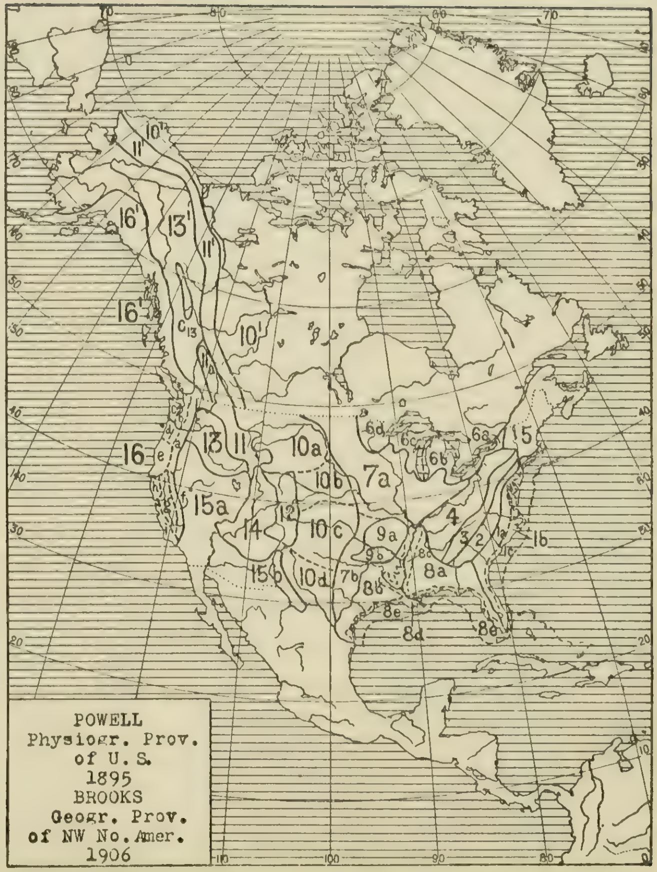
POWELL
Physiogr. Prov.
of U.S.
1895
BROOKS
Geogr. Prov.
of NW No. Amer.
1906
1b
2
3
4
6a
6b
6c
6d
7a
7b
8a
8b
8c
8d
8e
9a
9b
10'
10a
10b
10c
10d
11
11'
12
13
13'
14
15
15a
15b
16
16'
c13

FIG. 8.

FIG. 7.—From C. R. Dryer: High School Geography: Physical, Economic, and Regional, 1911, Fig. 302, Physiographic Provinces and Regions of North America, 1:70,000,000, and Fig. 57, Physiographic Provinces (map of the world, Mollweide's projection, equatorial scale, 1:156,000,000).

- 1 Laurentian Peneplain
    - H_1 Hudson Bay Coastal Plain
- 2 Greenland Plateau
- 3 Appalachian Highland
    - (northern part)
        - 3a New England Plateau
        - 3b Newfoundland
    - (southern part)
        - 3c Appalachian Ridges
        - 3d Piedmont Plateau
        - 3e Appalachian Plateau
    - O_3 Ozark Plateau
- 4 The Cordilleras
    - 4a Rocky Mountains
    - 4b Pacific Ranges
    - 4c Intermont Plateaus
        - 4c_1 Yukon Plateau
        - 4c_2 Columbia Plateau
        - 4c_3 Great Basin
        - 4c_4 Colorado Plateau
            - Wc_4 Wasatch Mountains
        - 4c_5 Mexican Plateau
- 5 Caribbean Ranges
- 6 Interior Plains
    - 6a Arctic Archipelago
    - 6b Arctic Coastal Plain
    - 6c Mackenzie Plain
    - 6d High Plains
    - 6e Glacial Drift Plain
- 7 Atlantic Coastal Plain

FIG. 8.—From J. W. Powell: Physiographic Regions of the United States (in: The Physiography of the United States, *National Geographic Society Monographs*, 1896), map on pp. 98 and 99, Physiographic Regions of the United States, 1:14,000,000; and A. H. Brooks: The Geography and Geology of Alaska (*U. S. Geological Survey Prof. Paper No. 45*, 1906), Pl. II, Geographic Provinces of Northwestern North America, 1:21,000,000.

- 1 Atlantic Plains
    - 1a Emerged Plains (subaërial)
    - 1b Coastal Marshes
    - 1c Submerged Plains (submarine)
- 2 Piedmont Plateaus
- 3 Appalachian Ranges
- 4 Allegheny Plateaus
- 5 New England Plateaus
- 6 Lake Plains
    - 6a-6d four subdivisions, as shown
- 7 Prairie Plains
    - 7a glaciated
    - 7b non-glaciated
- 8 Gulf Plains
    - 8a East Gulf Plain
    - 8b West Gulf Plain
    - 8c Flood Plain of the Mississippi
    - 8d Coastal Marshes
    - 8e Submerged Plains
- 9 Ozark Mountains
    - (9a Ozark Plateaus)
    - (9b Ozark Ranges)
- 10 Great Plains (*or* Plateaus)
    - 10a Missouri Plateaus
    - 10b Platte Plateaus
    - 10c Arkansas Plateaus
    - 10d Pecos Plateaus
- 11 Stony Mountains
- 12 Park Mountains
- 13 Columbia Plateaus
- 14 Colorado Plateaus
- 15 Basin Ranges
    - 15a Closed Basins
    - 15b Open Basins
- 16 Pacific Mountains
    - 16a Cascade Mountains
    - 16b Sound Valley
    - 16c Olympic Mountains
    - 16d Oregon Mountains
    - 16e Klamath Mountains
    - 16f Sierra Nevada
    - 16g California Valley
    - 16h North Coast Range
    - 16i South Coast Range
- 10′ Arctic Slope and Great Plains Region
- 11′ Rocky Mountain System
    - 11a Gold Ranges
- 13′ Central Plateau Region
    - C_{13} Cassiar Mountains
- 16′ Pacific Mountain System

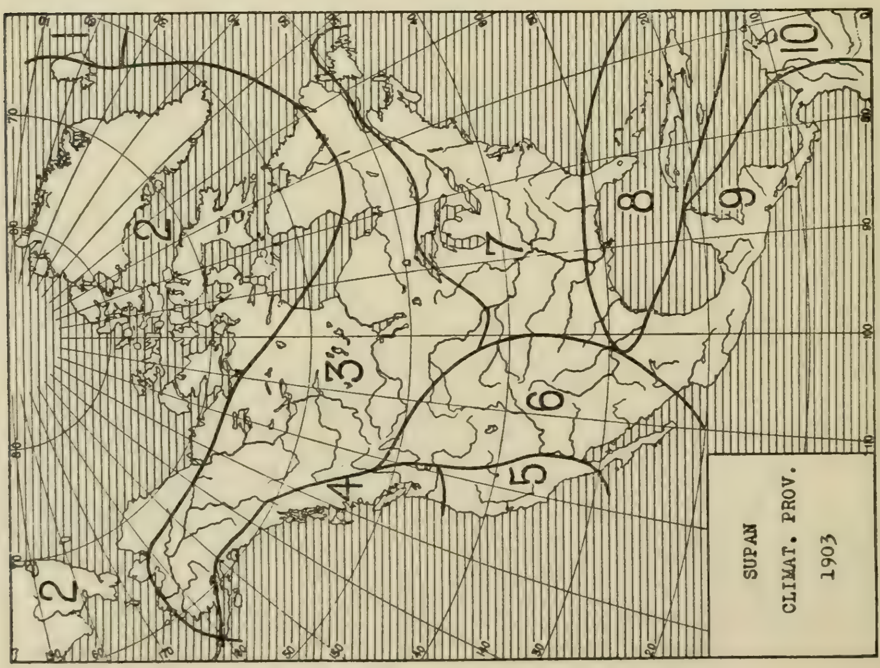
SUPAN
CLIMAT. PROV.
1903
1
2
3
4
5
6
7
8
9
10

FIG. 9.

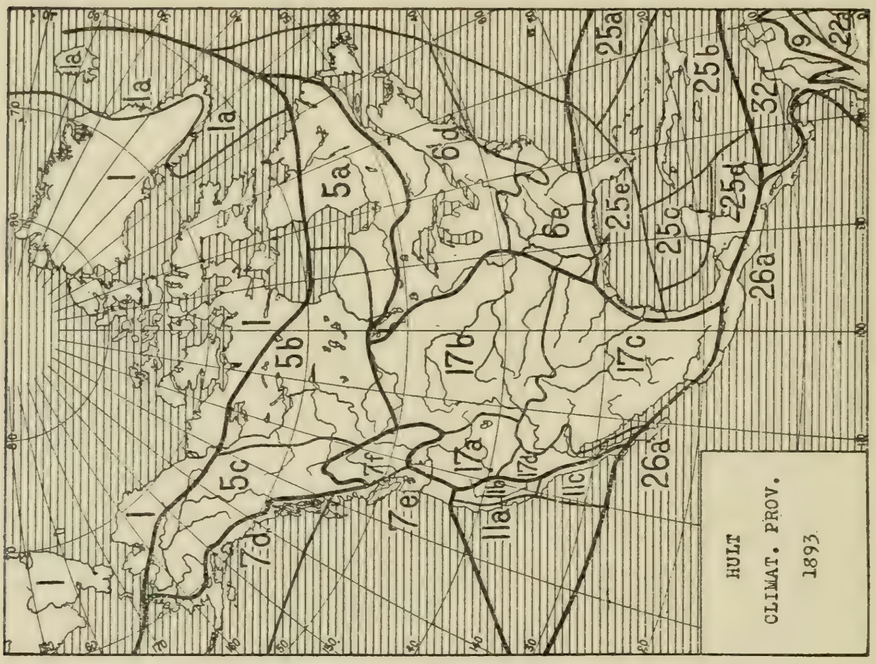
HULT
CLIMAT. PROV.
1893
1
1a
5a
5b
5c
6d
6e
7d
7e
7f
11a
11b
11c
17a
17b
17c
17d
25a
25b
25c
25d
25e
26a
32
22a

FIG. 10.

FIG. 9.—From A. Supan: Grundzüge der physischen Erdkunde (5th edit., 1911), Pl. XV, Die Klima-Provinzen (map of the world, Mercator's projection, equatorial scale, 1:125,000,000), unaltered from preceding editions.

1 [Western European Province]
2 Arctic Province
3 Hudson (North Canadian) Province
4 Northwest American Coastal Province
5 Californian Province
6 North American Mountain and Plateau Province
7 Atlantic (East North American) Province
8 West Indian Province
9 Tropical Cordilleran Province
10 [Tropical Province of South America]

FIG. 10.—From R. Hult: Jordens klimatomraden: Försök till en indelning af jordytan efter klimatiska grunder, *Vetensk. Meddel. af Geogr. Föreningen i Finland* (Helsingfors), Vol. 1, 1892-93, pp. 140-201, Pl. XVI (map of the world, Mollweide's projection, equatorial scale, 1:150,000,000).

- A Cold Climates
  - I with cold summers
    - 1 Arctic Region
      - 1a North Atlantic Province
  - II with warm summers
    - 5 Hudson Bay Region
      - 5a James Bay Province
      - 5b Mackenzie Province
      - 5c Yukon Province
- B Temperate Climates
  - I with rain at all seasons
    - 6 Gulf Stream Region
      - 6d Canadian Province
      - 6e Southern States Province
    - 7 Kuro Shio Region
      - 7d Aleutian Province
      - 7e Cascade Range Province
      - 7f Fraser Province
    - [9 Andes Region]
  - II with winter rains and dry summers
    - 11 Californian Region
      - 11a Coast Range Province
      - 11b Sacramento Province
      - 11c San Diego Province
  - III with summer rains and dry winters
    - 17 Rocky Mountains Region
      - 17a Utah Province
      - 17b Prairie Province
      - 17c Mexican Province
      - 17d Mohave Province
- C Warm Climates
  - [I with solstitial rains and without a pronounced wind system
    - 22 Llanos Region
      - 22a Orinoco Province]
  - II with trade winds
    - 25 Caribbean Region
      - 25a Central Atlantic Province
      - 25b Antilles Province
      - 25c Yucatan Province
      - 25d Mosquito Province
      - 25e Louisiana Province
    - 26 Pacific Region
      - 26a Tehuantepec Province
  - [IV with heavy rains at all seasons
    - 32 Colombia Province]

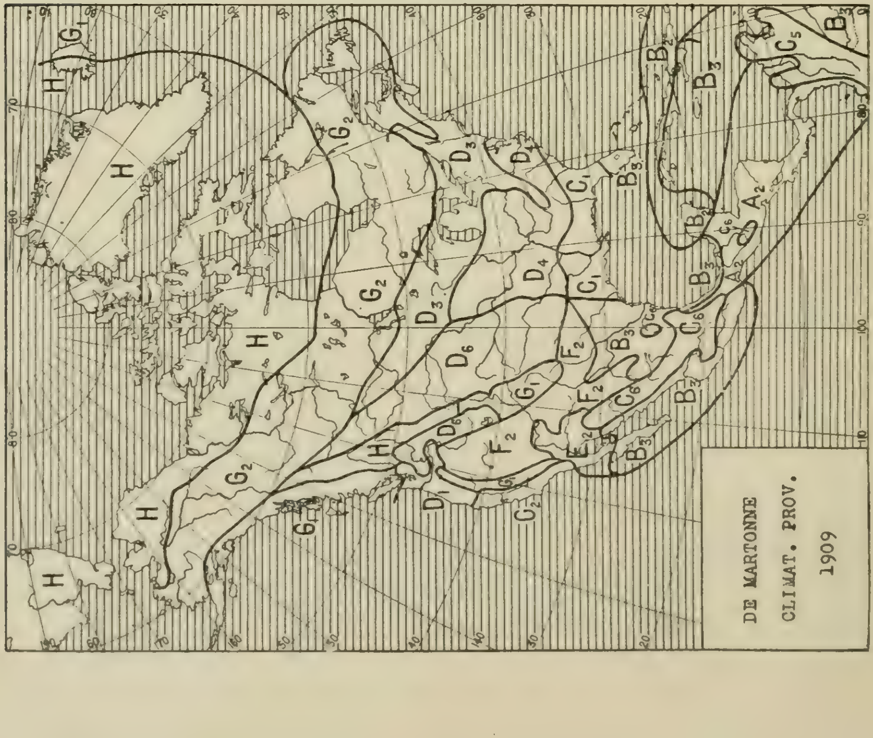
DE MARTONNE
CLIMAT. PROV.
1909
H
G₁
G₂
D₁
D₃
D₄
D₆
C₁
C₂
C₅
C₆
B₂
B₃
A₂
F₂
E₂

FIG. 11.

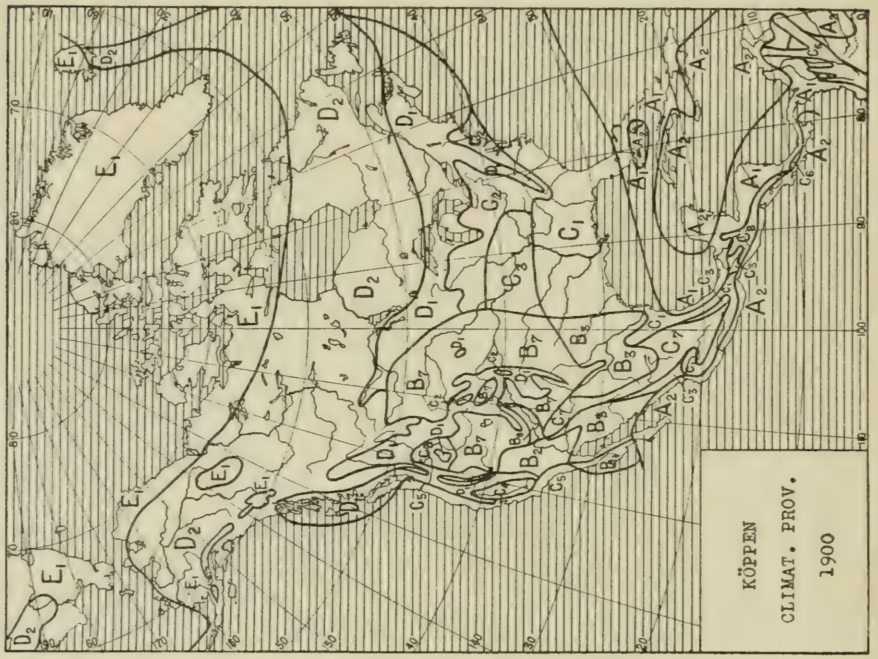
KÖPPEN
CLIMAT. PROV.
1900
E₁
D₁
D₂
C₁
C₂
C₃
C₅
C₆
C₇
C₈
B₂
B₃
B₄
B₅
B₇
B₈
A₁
A₂

FIG. 12.

FIG. 11.—From E. de Martonne: Traité de Géographie Physique (2nd edit., 1913), Carte des Climats (map of the world, Mollweide's projection, equatorial scale 1:100,000,000), unaltered from first edition.

Hot Climates
Equatorial Climates
A_2 Amazonian
Tropical Climates
B_2 Sudan
B_3 Senegal
Subtropical Climates
C_1 Chinese
C_2 Portuguese (Mediterranean oceanic)
C_6 Mexican
Temperate Climates
D_1 Brittany
D_3 Polish
D_4 Danubian
D_6 Ukrain
Desert Climates
E_2 Saharan
F_2 Aral
Cold Climates
G_1 Norwegian
G_2 Siberian
H Arctic

FIG. 12.—From W. Köppen: Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt, *Geogr. Zeitschr.*, Vol. 6, 1900, pp. 593-611 and 657-679, Pl. 6 (map of the world on Mercator's projection, equatorial scale, 1:95,000,000), reproduced in R. DeC. Ward: Climate, Considered Especially in Relation to Man, 1908, Fig. 17, and I. Bowman: Forest Physiography, Fig. 13.

Megatherms
A_1 Liana Climate
A_2 Baobab Climate
Xerophytes
B_1 Garua Climate
B_2 Simûm Climate
B_3 Mesquite Climate
B_7 Prairie Climate
Mesotherms
C_1 Camellia Climate
C_2 Hickory Climate
C_3 Corn Climate
C_4 Olive Climate
C_5 Heath Climate
C_6 Fuchsia Climate
C_7 High Savanna Climate
Mikrotherms
D_1 Oak Climate
D_2 Birch Climate
Hekistotherms
E_1 Ice Fox Climate

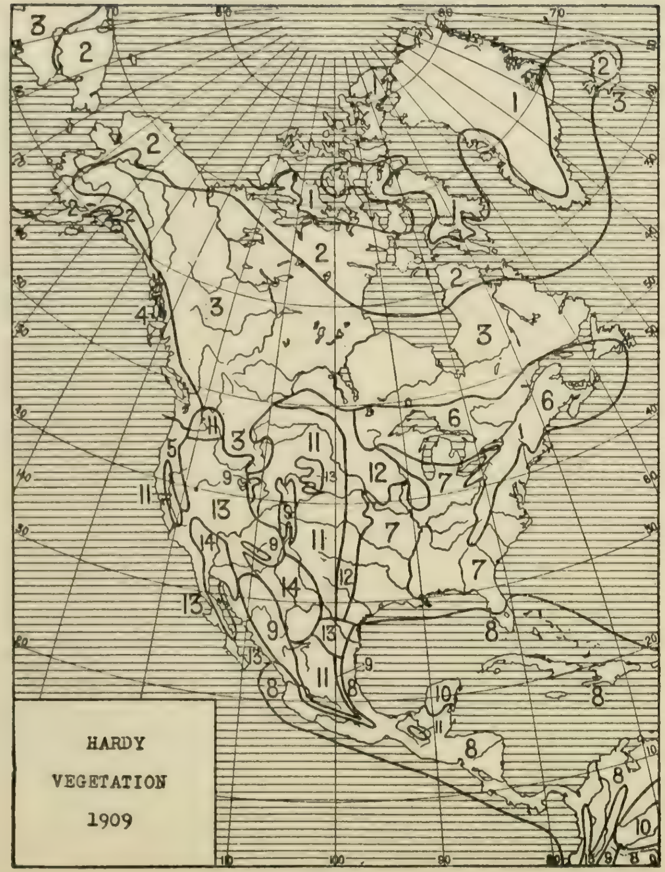
HARDY
VEGETATION
1909
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Fig. 13.

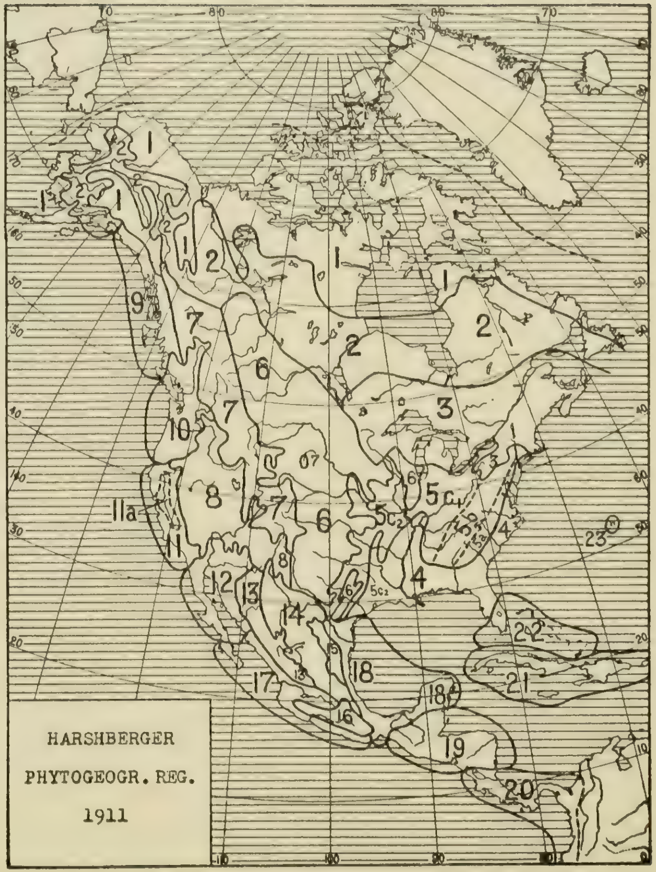
HARSHBERGER
PHYTOGEOGR. REG.
1911
1
2
3
4
5
5c₁
5c₂
6
7
8
9
10
11
11a
12
13
14
15
16
17
18
19
20
21
22
23

Fig. 14.

FIG. 13.—From M. E. Hardy: An Introduction to Plant Geography (in series: *The Oxford Geographies*), 1913, Fig. 62, Vegetation of North America, 1:70,000,000, simplified from *idem:* North America: Vegetation (*Oxford Wall Maps*), 1:7,500,000, 1909.

1 Snow
2 Tundra
3 Coniferous }
4 Pacific Temperate }
5 Mediterranean }
6 Mixed Temperate } **Forest**
7 Warm }
8 Hot Wet }
9 Mountain }
10 Savanna
11 Steppe
12 Park Steppe
13 Scrub
14 Desert
[15 Lofty Mountain]

FIG. 14.—From J. W. Harshberger: Phytogeographic Survey of North America (*Vegetation der Erde, VIII*), 1911, vegetational map of North America, 1:40,000,000.

1 Arctic Region (Greenland not considered)
2 Sub-Arctic Region
3 St. Lawrence-Great Lakes Region
4 Atlantic-Gulf Coastal Region
5 Appalachian-Ozark Region
  5a Piedmont District
  5b Appalachian District
  5c Alleghenian-Ozark District
    $5c_1$ Allegheny Plateau Area (including Lacustrine Area)
    $5c_2$ Ozark Area
6 Prairie-Great Plains Region
7 Rocky Mountain Region
8 Great Basin Region
9 Sitka Region
10 Columbian Region
11 Californian Region
  11a San Joaquin District
12 Sonoran Desert Region
13 Western Sierra Madre Region
14 Chihuahuan Desert Region
15 Eastern Sierra Madre Region
16 United Cordilleran Region ("mass of mountain ranges formed by the union of the W and E Sierra Madre chains")
17 Jaliscan Region
18 Gulf Region
19 Guatemalan Region
20 Costa Rican Region
21 Antillean Region
22 Bahaman Region
23 Bermudan Region

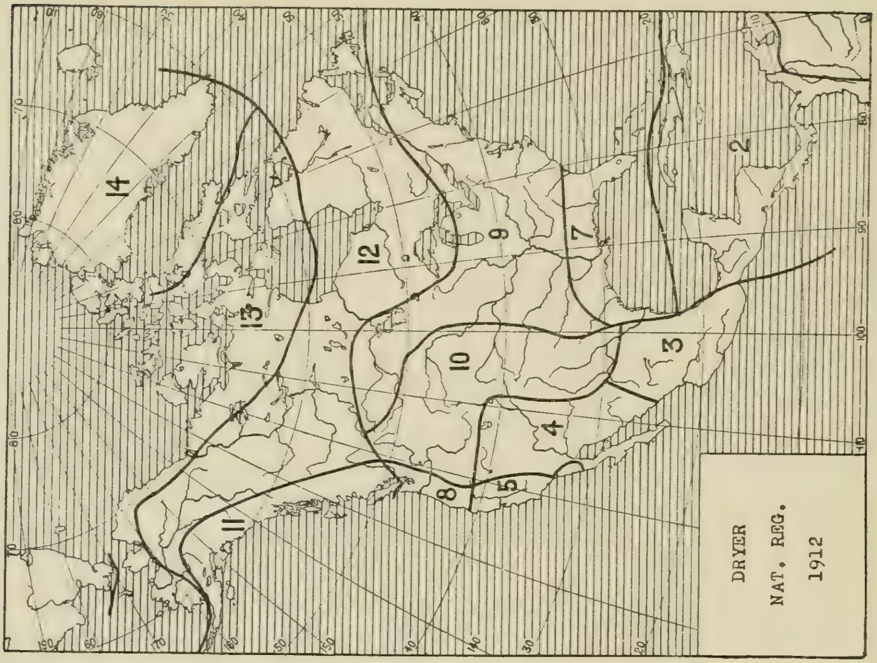
DRYER
NAT. REG.
1912
14
13
12
11
10
9
8
7
5
4
3
2

FIG. 16.

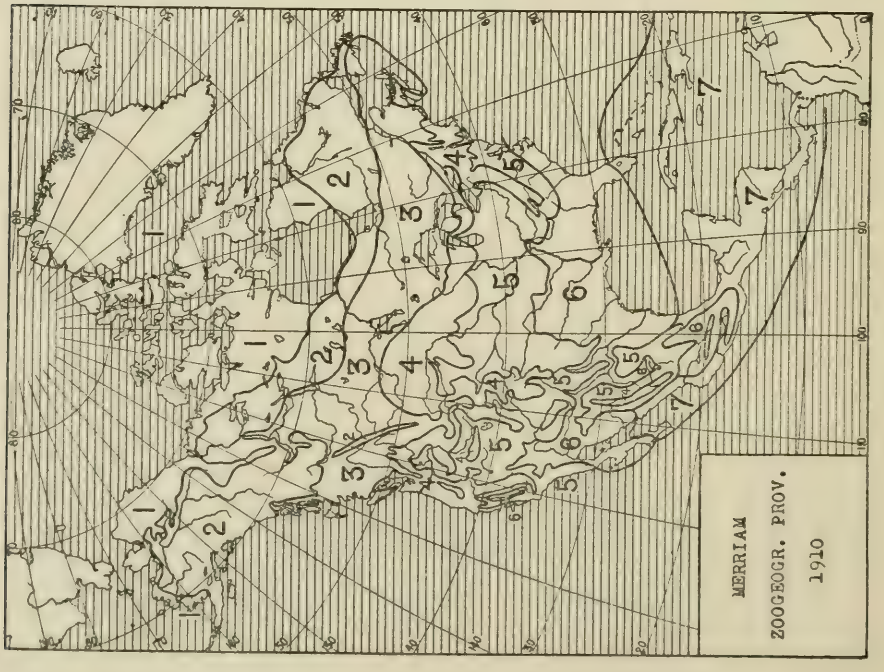
MERRIAM
ZOOGEOGR. PROV.
1910
1
2
3
4
5
6
7

FIG. 15.

FIG. 15.—Simplified from: Check-List of North American Birds, prepared by American Ornithologists Union (3rd edit., 1910), frontispiece, U. S. Biological Survey Fourth Provisional Zone Map of North America by C. Hart Merriam, Vernon Bailey, E. W. Nelson and E. A. Preble, 1910, 1:39,000,000.

- Boreal Region
  - 1 Arctic Zone
  - 2 Hudsonian Zone
  - 3 Canadian Zone
- Austral Region
  - 4 Transition Zone
  - 5 Upper Austral Zone
  - 6 Lower Austral Zone
- Tropical Region
  - 7 Tropical Zone

Not all "islands" due to altitude are shown.

FIG. 16.—From C. R. Dryer: High School Geography, 1911, Fig. 307, Natural and Political Divisions of North America, 1:72,000,000, and Fig. 301, Natural Provinces (map of the world, Mollweide's projection, equatorial scale, 1:177,000,000). See also *idem:* The North America of To-Day and To-Morrow and Indiana's Place in It, *Proc. Indiana Acad. Sci.*, 1911, pp. 37-54, maps of North America, 1:34,000,000, Fig. 1, Pedographic Provinces, Fig. 3, Vegetation, Fig. 4, Natural Provinces.

- I Intertropical Provinces
  - 2 Caribbean type
  - 3 Mexican type
- II Subtropical and Warm Temperate Provinces
  - 4 Arizonan type
  - 5 Californian type
  - 7 Floridan type
- III Temperate and Intemperate Provinces
  - 8 Oregon type
  - 9 Mississippian type
  - 10 Interior type
- IV Cold Temperate Provinces
  - 11 Alaskan type
  - 12 Canadian type
- V Polar Provinces
  - 13 Arctic type
  - 14 Greenland type

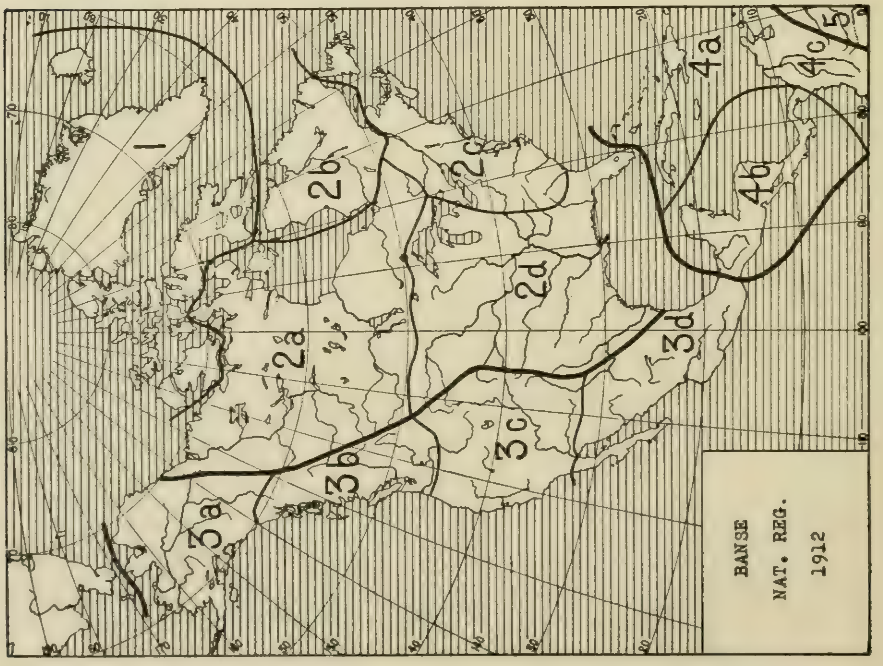
BANSE
NAT. REG.
1912
1
2a
2b
2c
2d
3a
3b
3c
3d
4a
4b
4c
5

Fig. 17.

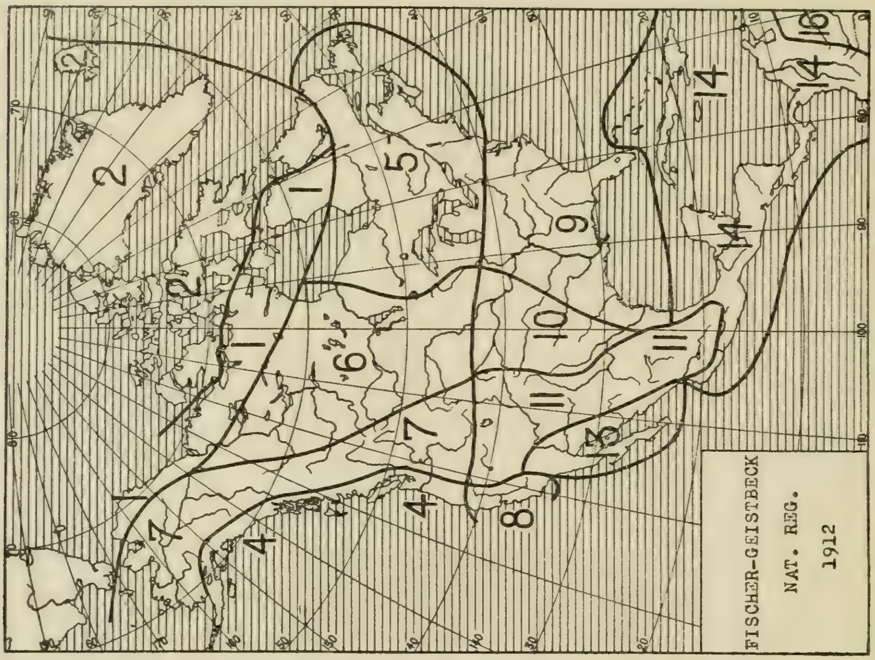
FISCHER-GEISTBECK
NAT. REG.
1912
1
2
4
5
6
7
8
9
10
11
13
14
16

Fig. 18.

FIG. 17.—From E. Banse: Geographie, *Petermanns Mitt.*, Vol. 58, I, 1912, pp. 1-4, 69-74 and 128-131, Pl. I (map of the world, Mollweide's projection, equatorial scale, 1:100,000,000). Nomenclature modified on map of world (Hammer-Aïtoff projection, equatorial scale, 1:95,000,000) accompanying: Illustrierte Länderkunde, edited by E. Banse, 1914.

1 Arctis
2 America
    2a Canada } (Hudsonia)
    2b Labrador } (Hudsonia)
    2c Appalachia
    2d Missouria
3 Greater California (Cordilleria)
    3a Alaska
    3b Columbia (British Columbia)
    3c California (Greater California)
    3d Mexico
4 Andina
    4a Antilles (West Indies)
    4b Panama (The Isthmuses)
    [4c Ecuador] ({Colombian, Ecuadorian, Bolivian} Andes)
[5 Amazonia]

The names in parentheses are alternatives used in the "Illustrierte Länderkunde."

FIG. 18.—From H. Fischer and M. Geistbeck: Stufenatlas für Höhere Lehranstalten, III: Oberstufe, 1912, p. 18, Geographische Gebiete der Erde auf Grund des Klimas und der Landesnatur, nach Herbertson, Friedrich und Ambrosius (map of the world, Hammer-Aïtoff projection, equatorial scale, 1:210,000,000).

Polar Zone
    1 Regions of tundra type
    2 " " Greenland type
Temperate Zone
    4 Regions of western European type
    5 " " Manchurian type
    6 " " Siberian type
    7 " " Altai type
Subtropical Zone
    8 Regions of Mediterranean type
    9 " " China type
    10 " " Turan type
    11 " " Iran type
Tropical Zone
    13 Regions of Sahara type
    14 " " tropical monsoon type
    [16 " " Sudan type]

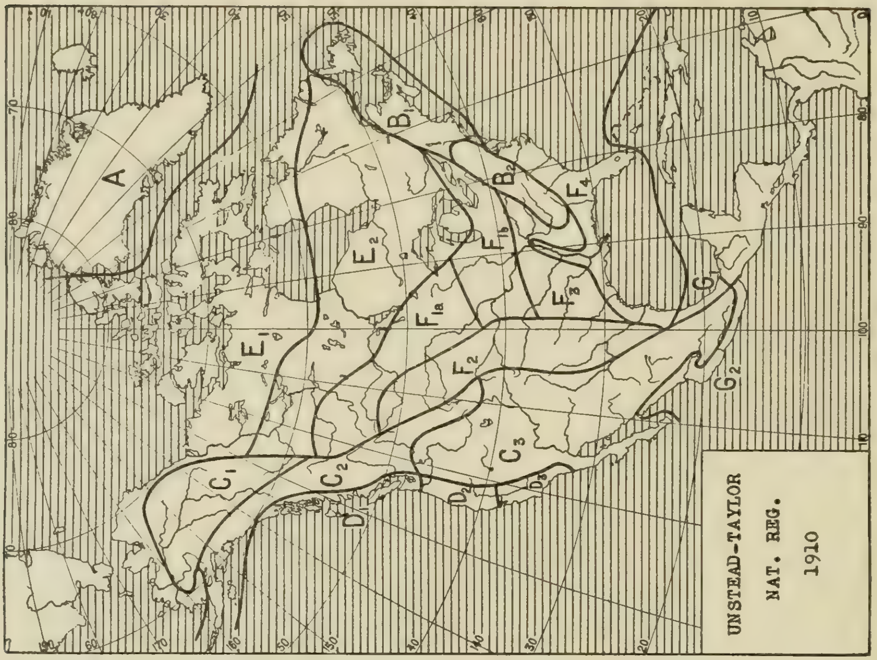
A
B1
B2
E2
F1b
F4
F1a
F3
G
E1
F2
G2
C1
C2
C3
D1
D2
D3
UNSTEAD-TAYLOR
NAT. REG.
1910

FIG. 20.

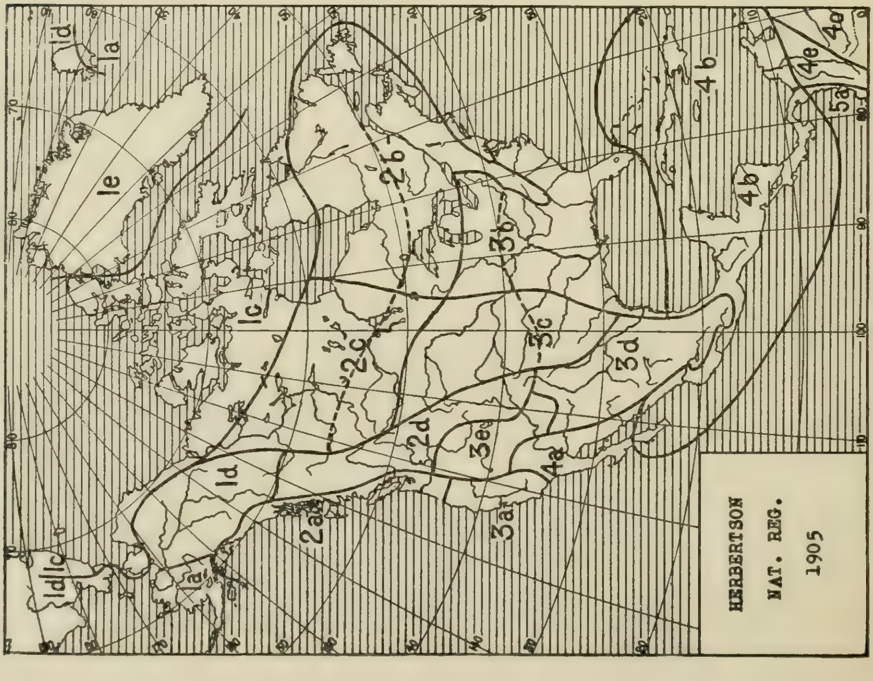
1d
1a
1e
1c
2b
2c
3b
3c
3d
2d
3e
4a
2a
3a
4b
4e
5a
1d 1c
1a
HERBERTSON
NAT. REG.
1905

FIG. 19.

FIG. 19.—From A. J. Herbertson: The World: Natural Regions (*Oxford Wall Maps*, No. 8, 1912), Mollweide's projection, equatorial scale 1:33,300,000. See also map on p. 308 of the paper in the *Geogr. Journ.*, Vol. 25, 1905, referred to in footnote 1 and map facing p. 1 in A. J. and F. D. Herbertson: The Senior Geography (*The Oxford Geographies*, Vol. III), 1907.

[1a Norway]
1c Tundra
1d Yukon
1e Greenland
2a Western Europe
2b St. Lawrence
2c Siberia
2d Baikalia
3a Mediterranean
3b China
3c Turan
3d Iran
3e Mongolia
4a Sahara
4b India
[4c Sudan
4e Quito
5a Amazon]

Numbers indicate climate, viz. (1) cold, (2) cool, (3) warm, (4) and (5) hot; letters, physical features, viz. (a) western margin, (b) eastern margin, (c) central lowland, (d) highland or plateau, (e) lofty mountains and plateaus. Broken lines show subdivisions.

FIG. 20.—From J. F. Unstead and E. G. R. Taylor: General and Regional Geography for Students (2nd edit., 1911), Fig. 129, North America: Natural Regions, 1:68,000,000.

A Greenland
B The Appalachian System
  B_1 The Northern Region
  B_2 The Southern Region
C The Western Highlands
  C_1 The Alaskan Highlands
  C_2 The Northern Ridges and Valleys
  C_3 The Southern Basins and Plateaus
D The Western Margins
  D_1 The Temperate Region
  D_2 The Transition Region
  D_3 The "Mediterranean" Region
E The Northern Plains
  E_1 The Barren Lands
  E_2 The Northern Forests
F The Central Plains
  F_1 The Prairies
    F_{1a} with long, severe winters
    F_{1b} with shorter, milder winters
  F_2 The High Plains
  F_3 The Lower Mississippi Basin
  F_4 The Mississippi Flood-Plain and the Coastal Plains
G The Tropical Margins of Mexico
  G_1 The Eastern Margin
  G_2 The Western Margin

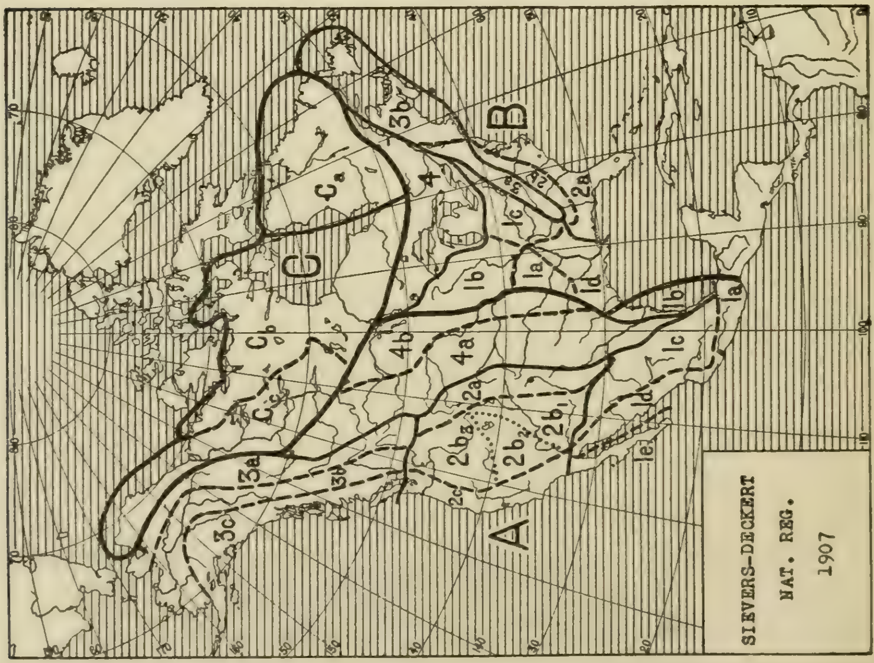
SIEVERS-DECKERT
NAT. REG.
1907
A
B
C
Ca
Cb
Cc
1a
1b
1c
1d
1e
2a
2b1
2b2
2b3
2c
3a
3b
3c
4
4a
4b

FIG. 21.

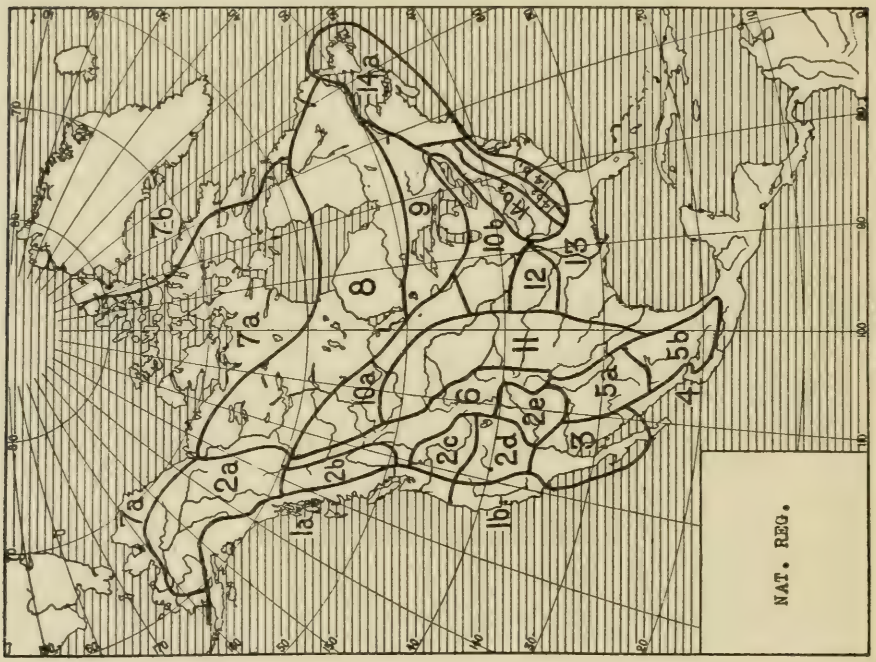
NAT. REG.
1a
1b
2a
2b
2c
2d
2e
3
4
5a
5b
6
7a
7b
8
9
10a
10b
11
12
13
14a
14b

FIG. 22.

FIG. 21.—From W. Sievers: Allgemeine Länderkunde: Kleine Ausgabe, Vol. 1, 1907, Nord-Amerika: Natürliche Landschaften, [based on E. Deckert], 1:37,600,000, between pp. 152 and 153.

- A Cordilleran North America
  - 1 Southern Cordilleran Land (Mexico)
    - 1a Southern Margin
    - 1b Eastern Margin
    - 1c Interior Highland
    - 1d Western Margin
    - 1e Lower California
  - 2 Central Cordilleran Land (United States)
    - 2a Eastern Mountain Belt
    - 2b Interior Highlands
      - $2b_1$ Colorado Plateau
      - $2b_2$ Great Basin
      - $2b_3$ Columbia Plateau
    - 2c Western Mountain Belt
  - 3 Northern Cordilleran Land (Canada, Alaska)
    - 3a Eastern Mountain Belt
    - 3b Interior Highlands
    - 3c Western Mountain Belt
  - 4 Prairie Plateau
    - 4a Upper Level
    - 4b Lower Level
- B Appalachian North America
  - 1 Mississippi Basin
    - 1a Ozark Mountains
    - 1b Upper Mississippi Basin
    - 1c Ohio Basin
    - 1d Mississippi Lowland
  - 2 Southeastern Plain
    - 2a Coastal Plain
    - 2b Piedmont
  - 3 Appalachian Mountain System
    - 3a Northern Appalachians
    - 3b Southern Appalachians
  - 4 The Great Lakes and St. Lawrence Region
- C Arctic North America
  - Ca Labrador
  - Cb Hudsonia
  - Cc Mackenzie Region

FIG. 22.—Tentative subdivision suggested by the writer.

- Cordillera
  - 1 Western Mountain Border
    - 1a with cool climate
    - 1b with warm climate
  - 2 Central Plateaus
    - 2a Yukon Plateau
    - 2d British Columbia Plateau
    - 2c Columbia Plateau
    - 2d Great Basin
    - 2e Colorado Plateau
  - 3 Sonoran Desert Region
  - 4 Pacific Coastal Plain
  - 5 Mexican Plateau
    - 5a Chihuahua Desert Region
    - 5b Anahuac Plateau
  - 6 Eastern Mountain Border (= Rocky Mountain System)
- Non-Cordilleran North America
  - 7 Arctic Region
    - 7a Tundra Lowlands
    - 7b Ice-capped Highlands
  - 8 Northern Coniferous Forest
  - 9 Great Lakes Region
  - 10 Prairie Region
    - 10a with long, severe winters
    - 10b with shorter, milder winters
  - 11 Great Plains
  - 12 Ozark Highland
  - 13 Gulf and Atlantic Coastal Plain
  - 14 Appalachian Highland
    - 14a Northern
    - 14b Southern
      - $14b_1$ Piedmont
      - $14b_2$ Appalachian Mountains
      - $14b_3$ Appalachian Plateau

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PHYSIOGRAPHIC BOUNDARIES WITHIN THE UNITED STATES

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CONTENTS

	Page
Introduction	84
Atlantic and Gulf Coastal Plain	90
Piedmont	91
Blue Ridge and Southern Appalachians	94
Appalachian Valley and Ridges	96
Allegheny-Cumberland Plateau	98
Interior Low Plateau	100
New England Region	101
Lake Region	104
Ozark-Quachita Region	107
Central Low Plains	109
Great Plains	113
Central Texas Hill Country	117
Northern and Western Rocky Mountains	119
Central Rocky Mountain Basin	121
Southern Rocky Mountains	122
Colorado Plateau	124
Desert Plateaus	126
Great Basin	127
Colorado Desert	130
Arizona and Trans-Pecos Highlands	131
Columbia Plateau	131
Cascade Mountains and Sierra Nevada	132
Coast Ranges	133
Pacific Coast Valleys	134

INTRODUCTION.—It is coming to be more desirable every year that geographers should come to an agreement as to the division of the United States into natural provinces. When first used, these boundary lines were sketched but not defined. This was sufficiently accurate for a discussion of the whole United States. Now, however, these province names and boundary lines are being freely used in the discussion of small units like counties and quadrangles. These are being referred to the several physiographic provinces. In doing this, regard is sometimes had to the old sketched boundaries. Oftener, the student of the smaller area decides for himself which larger province his area belongs to, or where the province boundaries should run. Present practice among geographers and geologists is very inconsistent. A quadrangle, county or half a state is assigned by one worker to one province and by another to another province, and when examined in detail, the formerly sketched lines may be found to cut through the middle of broad areas of uniform character.

The confusion will be worse when the plotting of census and other statistics by physiographic provinces has become common. Totals and averages will then differ according to the boundaries assumed. Even if one set of boundaries were used by all, the value of the results deduced would depend on the choice of lines in such a manner as to give physiographic and geographic unity to the several divisions. Therefore, while it is eminently desirable that the same boundaries be used by all, it is equally desirable that such lines be well chosen with reference to unity in each province.

It should be understood at the start that no one set of subdivisions of a continent can be made to serve in all discussions. The scheme of subdivision must vary according to the thing discussed. Climate and vegetation may well be, as has been said (Herbertson, Dryer and others) more important in man's environment than topography or even soil. Maps of major divisions of the earth's surface based on these criteria are of the utmost importance, but to compromise a map of physiographic provinces in order to show these data would end in showing neither one thing nor the other.

A map of major natural divisions of the earth's surface as given by Herbertson, takes account of physiographic provinces just as it does of the various climatic elements or of life zones and realms. It is a highly useful composite picture of the whole. It bears the same relation to a strictly physiographic map as it does to charts of the other elements named.

In a broad way the division of the United States into provinces serves two purposes; first, for the discussion and explanation of the physical features of the country; second, as a basis for the plotting and discussion of social, industrial, historical and other data of distinctly human concern. This second purpose is distinctively geographic. The first has its geographic side also but it is quite as much geologic as geographic. This paper is written in the conviction that these two purposes are consistent and that in serving the first, the physical criteria should be so handled as to serve the distinctly geographic purpose. The ever present considerations common to both purposes are topography and soils. They are, on the one hand, the end product and record of physiographic history and, on the other, the beginning of geographic development. These are therefore the most fundamental criteria in determining physiographic provinces. Subsidiary to these is geologic structure,—important where it controls topography, negligible elsewhere. Mere geologic age is immaterial but as difference in age is often accompanied by difference in character of rocks and therefore by contrasts in topography, it occurs frequently that province boundaries are drawn along geologic contacts. On this account in the definition and delimitation of natural divisions given below, mention of the underlying rocks is so frequent that the account might seem to have been written for geologists rather than for geographers. But ignoring the proper interests of geology, the one map which is useful beyond all others in the mere pointing out of physiographic boundaries is the geologic map. When province boundaries do not actually follow geological contacts, they may often be pointed out by reference to such lines rather than to political lines, meridians and parallels or even contour lines. Age names are frequently used in the paper which follows, even when age has nothing to do with the character of the formations, simply because the areas in question must be designated in some way and the critical reader will be more certain to have the geologic map before him than any other. Where not otherwise specified, references to the geologic map are to that of North America on the scale of 1 inch to 80 miles, issued by the United States Geological Survey.

"Unity or similarity of physiographic history" is a formula which *almost* designates the basis here in mind for the delineation of provinces. It implies that the topography throughout the province is all to be explained and described in the same story. It does not imply that it is superficially the same throughout the area. The Atlantic Coastal Plain is a well marked province but the hilly topography of its landward margin is superficially more like that of the adjacent Piedmont than like the featureless flats near the coast. It is, however, very much more nearly related to the latter, into which it grades without crossing any significant line of division. Recalling Davis's formula for topography—the product of structure, process and stage,—the hilly inner margin of the Coastal Plain differs from the flat outer margin only in stage. Four-fifths of the whole explanation is common to the two. Their explanations diverge only near the close. Hence in basing provinces on topography it is understood that the features throughout a province are *essentially related* rather than superficially alike. Excellent illustrations of this principle are found in the Lake Region and the Great Basin.

A division based on physiographic history would agree in the main with one based on topography because the latter is the product of the former. Every line drawn by the one criterion would appear also on a map drawn by the other criterion, but it might not have the same importance or rank; that is, a line separating major divisions on the one basis might separate subdivisions on the other. For the first use of physiographic provinces, namely the discussion and explanation of physical features, unity of physiographic history is the more important criterion. For geographic uses, topography is more important. The method followed in this study has been to hunt out and verify the most prominent lines which separate areas contrasted in topography. It is not claimed that all the important lines are here described or that all are of the same order of importance. The grouping of units is more or less a matter of taste and may vary according to the immediate purpose in hand. Hence it has not seemed necessary or desirable in this study to insist strongly on the rank which any line or areal unit shall have.

This last-named consideration (unity of physiographic history) is closely related to another—*convenience of treatment.* There is something almost final and authoritative in the requirement that a province be a convenient unit for discussion. This demand is not met if areas are linked together which must be explained by totally different stories. The modern and scientific method of describing, explaining and classifying topographies is based on their genesis;—hence the requirement here stated.

It thus appears that a province may be characterized by a single type of topography (as is almost true of the Allegheny Plateau, proper) or it may show a gradation by indefinable steps from one type to another (as in case of the Atlantic Coastal Plain). Further, it may consist of several types of topography causally related, mingled or distributed in a somewhat constant fashion (as the mountains and plains of the Great Basin).

A physiographic unit may then be defined as an area which is characterized throughout by similar or closely related surface features, and which is contrasted in these respects with neighboring areas.

Allowance must of course always be made for generalization. In treating the whole United States, provinces must be large. Inliers and outliers are inevitable. So also are some odds and ends which would constitute separate provinces if large, but, being small, must be thrown in with neighboring areas. But making due allowance for generalization, it is still true that the ideal limits of a province are such as admit of the *largest possible number of general statements* before details and exceptions are taken up. In proportion as this requirement is met, will it be made possible to describe a continent clearly and briefly.

The formula of Davis, basing topography on structure, process and stage has already been cited. More good topographic contrasts between adjacent areas are due to structure than to either of the other elements. This is abundantly illustrated below in tracing the province boundaries. Such a contrast may depend on the attitude of rocks as in case of the Rocky Mountains and the Colorado Plateau; or on their relative hardness as in a retreating escarpment like the edge of the Allegheny

Plateau in New York. In all such cases the contrast in structure has resulted in different erosional histories and different topographies.

Thus it comes about that geologic contacts are often the logical and the most convenient arbitrary lines for province boundaries, not because the rock underlying one area is old and that beneath its neighbor is young, but because their contrasted characters or ages have determined contrasted surface features.

As stated above, it has been the custom in physiographic discussions, especially of large areas, to sketch province boundaries with sufficient accuracy to illustrate a verbal statement but with no thought of having such a line identified in the field. It is not infrequently assumed that such lines have no existence in the field. It is evident that as soon as detailed study begins and writers on small areas begin to apply the names of major provinces, it becomes necessary to know where one province leaves off and another begins. With this point in view it becomes very desirable that province boundaries should, so far as possible, separate contrasted types of topography. Unless this condition is met there will be constant clashing between students of small areas and those who describe the larger units. Sketched boundaries are all right for the lecture room but it would be a pity if the recognition of physiographic provinces should end there.

On the other hand, while it is eminently desirable that province boundaries should correspond to visible contrasts in topography (the stronger such contrast the better) it will necessarily occur that such contrasts will be locally weak. If such circumstances were considered valid arguments against the division of the country into natural provinces no such division need be attempted. The important fact to be determined is whether a given region is strongly enough characterized to deserve separate treatment. That fact once settled, it remains only to choose the most consistent limits possible.

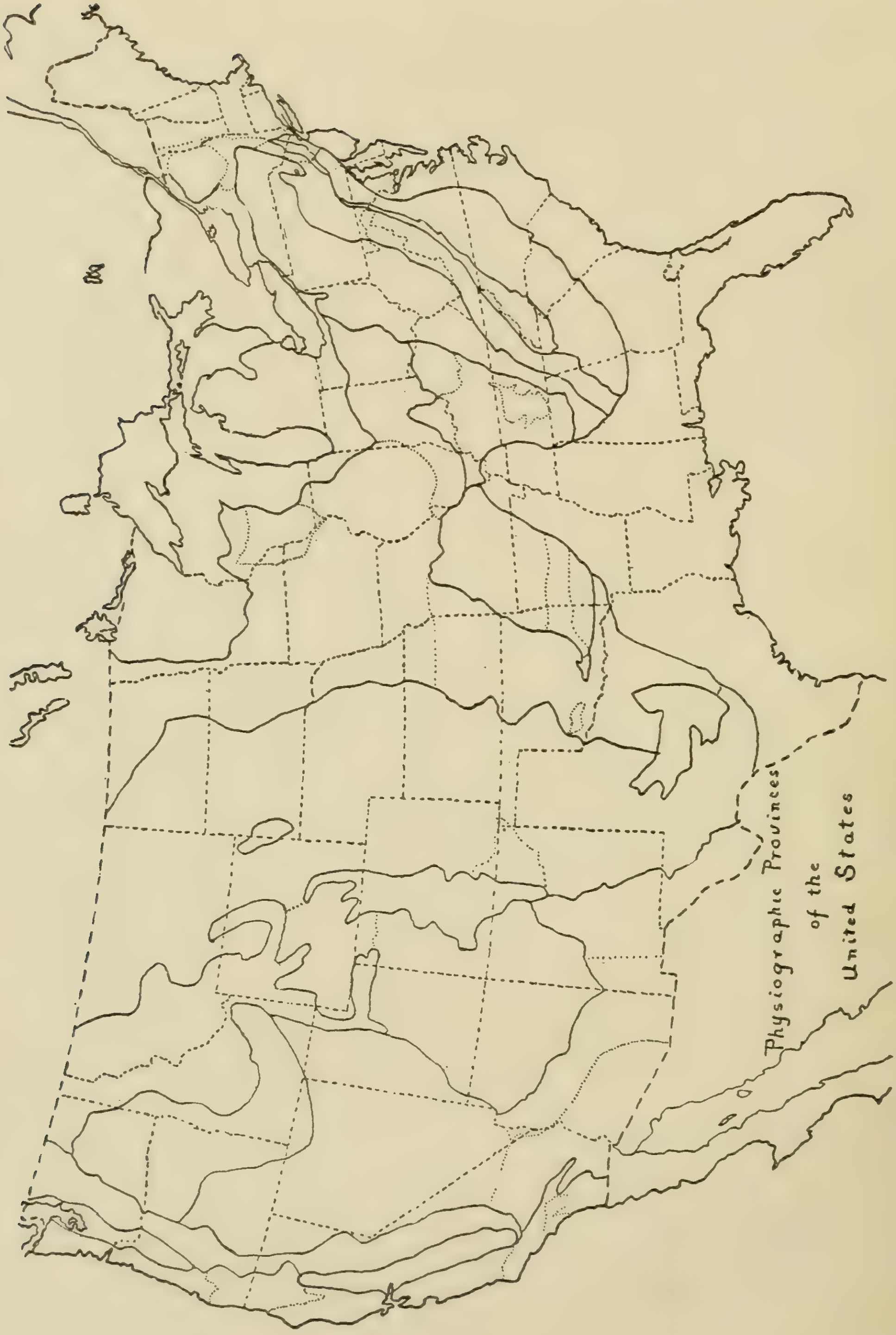
It is therefore the purpose of this paper (1) to divide the United States in such a manner that each division shall have the maximum of physiographic unity, (2) to base all boundary lines so far as possible, on important contrasts visible in the field, (3) to designate the most suitable arbitrary lines where such contrast in the field is not clear, (4) to interpret these boundary lines, so far as possible, in terms of geologic structure and physiographic history.

It is unnecessary to state that this study is based on earlier work by Powell and others. There has been no great departure from Powell's scheme of provinces though some new divisions have been made and some boundaries of his divisions have been much changed. The chief task here attempted is to find and define boundary lines, for there is no use speaking of natural divisions if there are no natural limits to such divisions and no use drawing lines if such lines might as well be drawn at one place as at another.

It can not be expected that this partition of the United States, or any other made at this stage, shall be in all respects the one which shall ultimately survive in general use. The lines here used are put forward in the hope of stimulating discussion and helpful criticism. This is especially invited from geologists and others with respect to those parts of the United States with which they have special acquaintance.

The word province has been used in so many senses by students of different sciences that it is scarcely possible now to use it in more than a non-technical sense designating a natural physical division. If the use of this word is to cause confusion with faunal provinces, present or past, or even with the provinces used by our Soil Survey, the word should be dropped. It is not of primary importance in the present effort, to decide which of these divisions shall be coordinate parts of the whole United States and which shall be subordinate members of larger provinces. In the normal development of any science involving classification, changes in the mere rank of this or that category are among the commonest marks of advance. With regard to any natural division of the United States, its mere rank in a scheme of subdivision is about the least important geographic fact to be known about it. Some of the divisions here given may be grouped and others subdivided to make the units which shall ultimately be regarded as coordinate. Among those whose parts may become major divisions are the New England region, the Ozark-Ouachita region and the Desert Plateaus. Or, instead of such division, the several Rocky Mountain provinces or the several Appalachian provinces may be grouped into large divisions. But neither grouping nor subdivision will cause recognition to be withdrawn from a well marked physical unit limited by natural boundaries. Only its rank may be changed. If the lines on the map here presented are physiographic boundaries of real importance, then any kind of geographic data plotted according to these divisions would not lose its value.

The lines as they stand here are sufficiently exact for the physical discussion of the several divisions as wholes. The map here presented is not however in the proper form for the plotting of census returns and other geographic data in which it is desirable to separate a province from its neighbors. For that purpose a new map must be constructed on which the present boundary lines shall be replaced by political lines conforming to them approximately but drawn by following the boundaries of the smallest political units possible. The enumeration district used in the census should be made the unit. It is customary to plot such data by counties. This should be continued



Physiographic Provinces of the United States

FIG. 1.

for counties lying wholly within a single natural division or where county boundaries agree approximately with the natural boundaries. Where a county is, to any significant degree, divided between two or more physical divisions, the physical line should be followed as nearly as possible by a zigzag line separating townships or enumeration districts. Few counties would have to be divided into more than two parts.

Such a zigzag line should be selected, *not* to conform as nearly as possible to the generalized physical boundaries here presented but by reference to the same detailed topographic and geologic maps from which the physical lines were drawn. In this way the errors due to generalization of the physical lines, may often be neutralized in the choice of political lines. Otherwise, the errors might very readily be cumulative.

The final result for the plotting of agricultural, commercial and other data would be a map of natural divisions whose boundaries would differ but little from those on the physical map. With such a base once made, the difficulty of plotting data would be no greater than at present, the only difference being that the number of units (counties and parts of counties) would be perhaps 50 per cent greater than at present. In present practice a county which is equally divided between a mountain province and a lowland, shows the conditions in neither one half nor the other, but an intermediate condition which does not represent either half correctly. Where counties are large or provinces narrow, the peculiarity of a province with reference to the distribution of this or that product is entirely lost.

Before the construction of such a base map as here described it is evident that the physical limits of the several natural divisions must be determined.

THE ATLANTIC AND GULF COASTAL PLAIN.—The Atlantic and Gulf Coastal Plain is a well defined physical division of the United States. It is itself capable of logical subdivision. It has long been customary to accept for the boundary throughout most of its extent the contact between the Cretaceous and younger rocks on the one hand and the Triassic and older rocks on the other. The essential element in this distinction is not the matter of age, but of structure and thereby of topography. Accepting the term coastal plain in its usual sense, its essential characteristic is a surface of low relief on the outcrop of undeformed strata bordering a land mass to which it has been added by uplift. Briefly it might be defined as that portion of the continental shelf which has been raised above water without deformation. The term, as generally used, connotes a constructional origin and excludes peneplains.

The boundaries of our Atlantic and Gulf Coastal Plain, as determined by custom, conform in large part to these definitions, but there are some exceptions. The inner edge of the coastal plain in Georgia and the Carolinas has not everywhere a topography of "low relief," but locally has hills 400 or 500 feet high. But as this part of the Coastal Plain differs only in degree and not in kind from that which is lower and flatter, there is no satisfactory province boundary between the coast and the edge of the Piedmont. Again, west of the Mississippi, both the language of the people and precedent in scientific writing[1] exclude the Cretaceous from the Coastal Plain. This may well be justified on the ground that erosion and even baseleveling on the Cretaceous have advanced so far that this area is no longer *primarily* an emerged sea bottom, but a denuded area allied in its physiographic history with the prairie province. There can be no objection to this arrangement if accepted by all so as to avoid confusion.

An alternative line in Texas would be the contact between the upper and lower Cretaceous which essentially agrees with the Balcones fault scarp as far north as Brazos River at Waco. North of that place the fault scarp is negligible. The limit of the coastal plain thus drawn would be in agreement with its definition as "that part of the continental shelf which has been lifted out of water without deformation." It would have the further advantage of classing the "Black Prairie" of Texas with its counterpart the "Black Belt" of Alabama. Both are Cretaceous and the latter is included by all writers in the Coastal Plain. This plan has however the disadvantage of separating the Blank and Grand Prairies of Texas by a major province boundary. In any case the narrow strip of upper Cretaceous between Austin and the Rio Grande may for convenience and for practical purposes be thrown into the Coastal Plain as it can not be included in the Edwards Plateau (Great Plains).

In defining the Coastal Plain as above, it is understood to include all alluvial plains within its limits. The most natural subdivisions are the alluvial plain of the Mississippi and those parts of the Coastal Plain which lie respectively west and east of this alluvial plain. The eastern part may be further subdivided for convenience of discussion.

THE PIEDMONT.—The Piedmont as a natural physical division may be defined as the plain or plateau portion of the Older Appalachians. Conventionally, the name is applied only to the portion west and south of Hudson River. As a mere matter of convenience in description and discussion it is well to respect this convention. Whether the Piedmont and the old mountains on the west shall be treated as separate provinces or as subdivisions of a larger province is a matter of taste. A student of distinctly geological bias would doubtless prefer the latter but geographic interests demand that the contrasts between these two portions be recognized in some way and even emphasized. In like manner the cutting off of this and other Appalachian provinces at or near the Hudson River is for geographic rather than geologic reasons.

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[1] Hill, R. T. Phys. Geog. of the Texas Region, U. S. Geol. Surv. Topographic Atlas, folio No. 3, and other papers.

The definition here given fixes the western limits of the Piedmont at the line where the plateau topography gives way to one of mountains. Isolated mountains (like the Catoctins and the trap ridges of New Jersey) entirely surrounded by relatively level surface, are of course included in the Piedmont. Throughout the greater part of the boundary thus fixed there is not much room for difference of opinion as to its location. In New York, New Jersey and Pennsylvania the topographic break occurs along the line of contact between the softer Triassic of the Piedmont and the harder Cambrian and pre-Cambrian.[2] In Maryland and Virginia as far south as the Chesapeake and Ohio Railroad west of Charlottesville, almost all of that which appears on the Virginia geological map (1911) as pre-Cambrian granite and granite gneiss belongs to the Piedmont, the boundary of the mountain area lying but little east of the strong Catoctin schist. This formation with the strong Lower Cambrian are the essential substrata of the Blue Ridge in this latitude. The same formations farther east make the Catoctins which are entirely within the Piedmont area.

South of Charlottesville and the Chesapeake and Ohio Railroad, geological contacts and contrasts seem to have nothing to do with determining the extent of mountain and plateau. The line traverses a belt of crystalline rocks which are not differentiated on available geological maps. The inner edge of the Piedmont has an elevation of about 800 feet just south of Charlottesville, but its altitude increases to 1,500 feet in southern Virginia, North Carolina and Georgia. A glance at most of the topographic sheets crossed by this boundary line is sufficient to show a contrast between the lower country with its gentler slopes and closely woven web of roads, and the mountain country with its closely crowded contour lines and absence of cultural features.

In north-west Georgia the number and size of outlying mountains on the edge of the Piedmont (Pine Log Mountain and others) is so great as to leave in doubt the propriety of terminating the mountain province at Coosawattee River or extending it southward in a narrow point to the Etowah at Cartersville. Hayes[3] does the latter but this appears only on a map of very small scale in which the mountain province is dealt with somewhat liberally. The narrow limit is here tentatively proposed.

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[2] Compare Pa. Geol. map 1893 with U. S. G. S. Topog. Sheets.

[3] Hayes, C. W. Physiography of the Chattanooga District, XIX Ann. Rep. U. S. Geol. Surv., Pl. 1.

In southeastern Pennsylvania where for forty miles there is a gap in the Blue Ridge, there is little contrast in topography between the Piedmont and the Appalachian Valley which touches it. The line here proposed follows arbitrarily the contact of Triassic rock, (typical of the northern Piedmont) and the older Paleozoic (typical of the newer Appalachians).

In Georgia and Alabama south of the mountain province, the Piedmont is terminated on the west not by a rise but by a fall to the Great Valley. This break follows essentially the line of contact between the pre-Cambrian and Ocowee (Cambrian) series on the one hand and the younger and weaker Cambrian and Ordovician on the other.[4]

The topographic break along this line is easily traced westward from Georgia into Alabama. Turning southward again in the latter state, the topographic break becomes less clear. This is partly because of the decreasing altitude of the Piedmont, but partly also because of outlying ridges on the strong Chilhowee (Cambrian) series, these ridges being partly or wholly surrounded by the valley floor and separated geologically from the Piedmont by outcrops of the upper and softer Cambrian formations. Hence in so far as the topographic break (and therefore the province boundary) can be referred to a geologic contact, it is drawn at the edge of the Ocowee outcrop. Farther north where the eastern boundary of the Great Valley is against the mountain province the Chilhowee rocks and the mountains which they form are included in the area of the latter.

The remaining boundaries of the Piedmont on the east and south are all against the Coastal Plain.

THE BLUE RIDGE AND SOUTHERN APPALACHIANS.—This province (or sub-province if preferred) affords the only case in which the liberty has been taken of including two separate areas under the same name. This is done in order to conform to custom and to avoid a multiplicity of small divisions. It is confessedly arbitrary, the more so, because its northern portion is contiguous with the similar New England province which is treated separately. However, in geographic, rather than geologic, discussions it is highly convenient to make an arbitrary separation along the line of Hudson River. West and south of that, all the Appalachian provinces except the one in question are continuous strips extending to the Gulf Coastal Plain. It is convenient to treat this province as one of these strips.

The boundaries of this division are well marked. At very few points along its boundary is there a zone of any considerable width whose reference to one province or the other might be in question.

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[4] See Geological Map of Northwestern Georgia—Georgia Geol. Survey, Bul. 23, 1910; also State Geological Map of Alabama.

It embraces mountain country only, and is bordered by lower plateau country and valley. The largest valley lands within this mountain province can be comprehended in a single view and are seen to be surrounded by mountains. Isolated mountains rise also within the neighboring provinces but they are entirely surrounded by the style of topography appropriate to those provinces. The line here given is along a topographic break as traced on the large scale sheets of the United States Geological Survey.

Throughout much of its extent this boundary line may be interpreted by noting its more or less close agreement with a geological contact. In such cases the logical description of the province is aided by using the line of contact as the province boundary, but it should be emphasized that the contact is used merely as a means of *interpreting* a line which has been fixed by other criteria. The western (or rather northwestern) boundary is thus determined throughout its entire length. For all practical purposes it agrees with the line where the stronger rocks of the pre-Cambrian or earlier Cambrian give way to the limestones and shales of the later Cambrian and Ordovician.

In New York and New Jersey where the mountain province is known as "The Highlands," it is composed almost entirely of pre-Cambrian rocks. At the contact of these with the Cambro-Ordovician beds on the west there is a clear and sharp topographic break. The same is true in Pennsylvania except that the "Cambrian quartzite" shown on the geological map of Pennsylvania (1893) must also be excluded from the valley province and counted in the mountain province to the east. This is not quite equivalent to drawing the province boundary between the Georgian and the later Cambrian, since the topmost member of the former as mapped in the Mercersburg-Chambersburg folio plainly belongs to the Great Valley. It is sufficient for the present to say that the quartzitic lower formations of the Cambrian, mapped by the Pennsylvania Survey as quartzite, lie within the mountain province and determine the boundary.

For a space of about forty miles adjacent to the Susquehanna River the mountain province is interrupted. Here the Great Valley must be arbitrarily delimited from the Piedmont, the topography of the two being very similar. It is convenient to draw the line along the contact between the Paleozoic rocks which everywhere underlie the Valley province and the Triassic rocks which are so highly characteristic of the Piedmont.

Crossing into Maryland, the line continues to be determined, as in Pennsylvania, by the hard sandstone members of the Cambrian which underlie (stratigraphically) what is here as elsewhere mapped as Cambro-Ordovician. The Weverton sandstone is the chief one of these in Maryland.[5]

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[5] Cf. Maryland Geological Map, 1906, with Harpers Ferry Topographic Sheet.

On the state geological map of Virginia (1911) the distinctively Cambrian formations (generally strong) are distinguished from the Cambro-Ordovician, consisting of limestone and shale. From the Potomac to the Tennessee boundary the topographic break between mountain and valley occurs at the contact between these strong Cambrian sandstones and quartzites on the east and the limestones and shales of the Cambro-Ordovician on the west. The line is closely followed in turn by the Shenandoah River, by a part of New River and by branches of the Holston. Throughout nearly the whole distance the Norfolk and Western railroad (or its branches) runs parallel to the line thus indicated, always on the side of the limestone and for more than half the distance it is less than five miles away from the contact.

In Tennessee the topographic break is likewise clear, as shown in the numerous folios of the United States Geological Survey. The older Cambrian, Ocowee and Chilhowee series, belong to the mountain province and the Knox Dolomite and younger formations to the Valley. The same relations continue in Georgia where the Ocowee series is not differentiated from the granite on the most recent geological map.[6] At about Lat. 34° 30′ the mountain province ends. South of this the valley province is bounded by the Piedmont. The southern limit and eastern boundary of the mountain province have been traced in speaking of the Piedmont.

The Appalachian Valley and Ridges.—The distinguishing characteristic of the Appalachian Valley province is a topography of parallel longitudinal valleys and mountain ridges made by erosion in the second cycle after folding and resulting generally in a trellised drainage. As thus defined, it is distinguished from all its neighbors by lines over which there will be little disagreement. The next province on the west has a plateau surface and (in general) dendritic drainage. The province on the east shows so little parallelism of valleys as to suggest at once a more complex history and rocks of different character.

To the northeast, in New York, this valley is continuous with that of the Hudson, which has a somewhat different geologic history and present topography. The unity of the province, both historically and topographically would therefore be lessened by extending it northward to include the Hudson Valley. Moreover, in so far as physiographic provinces should form a basis for the discussion of human relations, these two valleys each deserve somewhat specialized treatment. The line taken to separate the two must in any case be arbitrarily chosen. The Hudson river has been used oftener than any other. The stretch of river thus employed is from Catskill Creek (lat. 42° 15′), to the Highlands (lat. 41° 30′). An alternative line would be the Hudson-Delaware divide, located almost on the New York-New Jersey boundary. The edge of the glacial drift, near the New Jersey-Pennsylvania boundary might also be used.

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[6] Georgia Geological Survey, Bull. 23, 1910.

The southeastern boundary of this Valley province separates it from the Blue Ridge and Southern Appalachians and from the Piedmont. It has been traced and described in defining those provinces.

At its southwest end the valley province merges into the Coastal Plain with no sharp topographic contrast. For the sake of consistency elsewhere the boundary line should follow the inner edge of the Cretaceous rocks.

The northwestern boundary of the Appalachian Valley province is as follows: Beginning at the south in the vicinity of Birmingham, Ala., the eastern edge of the plateau is represented by Sand Mountain and farther north by Blount Mountain. These are east facing scarps of Carboniferous Coal Measures. Follow this scarp northward past Chattanooga where it bears the name Walden's Ridge. The scarp for a long distance is often called the Cumberland Front. Where this Cumberland Front is not mapped in the United States Geological Survey folios, the continuation of the same outcrop of Carboniferous Coal Measures is followed on the geological map of Alabama. At the foot of this scarp are Wills Valley south of Chattanooga, and others similar.

Lookout Mountain, Owens Mountain and the Cahaba coal field are isolated patches of Coal Measures more or less horizontal and having a plateau topography, entirely cut off from the plateau to the west by valleys which are typical of the Appalachian Valley province. If preferred, these minor areas may be included in the plateau province to the west. It should, however, be remembered that while they have a more or less typical plateau character, the valleys west of them are thoroughly typical parts of the Great Appalachian Valley. Moreover, these valleys are continuous with the Great Valley while the plateau remnants are isolated from the broad plateau to the west.

North of Chattanooga the line follows the foot of Walden's Ridge and Cumberland Mountain and thus the edge of the Carboniferous rocks. The same line may be traced northward into Pennsylvania between the plateau capped by Carboniferous rocks (usually Coal Measures but locally Lower Carboniferous) and the valley underlain by older rocks. The scarp is generally clear and the contrast of elevation and topography on the two sides is marked. The edge of the plateau bears in succession the names Sand Mountain and Blount Mountain in Alabama; Walden's Ridge and Cumberland Mountain in Tennessee and Kentucky; Stone Mountain, Powell Mountain, Stone

Ridge, Back Allegheny Mountain, Cheat Mountain and Allegheny Front in Virginia and West Virginia, besides numerous other local names. It overlooks in succession the valleys of Wills and Lookout Creeks in Alabama and Georgia; Tennessee River, Clinch River and its tributary Powells River, Bluestone and East Rivers (Pocahontas folio) Greenbrier River, Shavers Fork (Upper Cheat River), New Creek and Potomac River. The following railroads run essentially at the foot of the great scarp; the Alabama Great Southern railroad from Chattanooga southwest to where the province ends against the Coastal Plain; the Cincinnati Southern from Chattanooga to lat. 36° (Harriman Junction); branches of the Southern Railroad from this point north to lat. 36° 20′ (the jog in the Briceville quadrangle); the Norfolk and Western along Clinch River and to lat. 37° 30′; and the Chesapeake and Ohio along the Greenbrier.

In Maryland the edge of the plateau is called Dan's Mountain. It overlooks the Potomac River and its northern tributary Wills Creek, and is followed throughout its length and north into Pennsylvania by branches of the Baltimore and Ohio railroad.

From the southern boundary of Pennsylvania north and east to the elbow of the Susquehanna east of Williamsport the Front is perfectly definite. It is followed for forty miles by the Susquehanna River and for one hundred miles by the Bald Eagle branch of the Pennsylvania Railroad. Eastward from the west branch of the Susquehanna River the plateau surface is on the Pocono and Catskill formations and is essentially coextensive with these around the edges of the anthracite coal fields. The anticlinal Wyoming Valley makes a long northeasterly extension of the valley province surrounded by inward facing escarpments. At Mauch Chunk the regular northeast trend is resumed, the scarp being formed first by the Pocono formation and then by the Catskill, overlooking Delaware River and in turn Neversink Creek, Rondout Creek and Hudson River, also the Delaware and Hudson Canal and several railroads.

ALLEGHENY-CUMBERLAND PLATEAU.—The essential features of this province are those of a dissected plateau. Except on its western side in Tennessee and adjacent states all its boundaries are against other provinces which are *not* dissected plateaus. The southern half of its western boundary separates this province from the Interior Low Plateau (Highland Rim) which is likewise a dissected plateau but so clearly distinguished by its lower elevation that popular usage has made the distinction in name and recognizes the same boundary which is used by geologists. If preferred, these two provinces may be treated as subdivisions of a greater Appalachian plateau province. Powell did this, though his boundaries were sketched rather than defined, and on the north differed materially from the one here adopted.

The absolute altitude of this province is not a criterion for its delimitation. Its uplands rise above 3,000 feet near the middle and fall as low as 500 feet at the southern extremity in Alabama, but the topography remains that of a dissected plateau. Neither is the degree of dissection determinative for it is submaturely dissected in Alabama and past mature in eastern Ohio. In general the rocks are nearly horizontal. Folds are exceptional and give rise to certain local details of topography, not to its general character. In general they are surrounded by flat-lying strata. Thus the province is characterized by unity of structure and topography. Its northern end has been glaciated. In all but the most general treatments this should be made the basis of a subdivision.

Throughout at least four-fifths of its boundaries this province is higher than its neighbors and is separated from them by an escarpment. This escarpment is best known on the east side where it is known in succession from north to south as the Catskill Mountains, the Allegheny Front and the Cumberland Front. (For details see western boundary of Appalachian Valley.) No one system of rocks forms the plateau surface or makes the scarp everywhere. The upper Carboniferous is most general.

The southeastern boundary of this province has been discussed in speaking of the Appalachian Valley which it overlooks. The boundary was there traced from central Alabama to the Catskill Mountains in New York. Continuing northward, the plateau edge is determined by the outcrop of the Catskill formation to lat. 42° 15′. Here, between Schoharie and Catskill Creek, the Helderberg begins to cap a lower terrace which must be treated as a part of the plateau. The outcrop of the Helderberg determines the edges of this plateau north and west to beyond Oneida where the edge of the Onondaga takes its place. This continues to Lake Cayuga. Between this lake and Seneca Lake the edge of the plateau shifts to the outcrop of the Portage sandstone which it follows to a point south of Buffalo.

The line thus described from the Mohawk valley to Buffalo is essentially the south shore of the Pleistocene lake at the time when the first continuous lake stretched from the Erie basin to the Mohawk.[7]

Between a point south of Buffalo and southern Ohio the line here used as the limit of the Allegheny Plateau follows no outcrop indicated on the geological maps of New York, Pennsylvania or Ohio. To a point in northeastern Ohio it lies within the Devonian and beyond that in the Lower Carboniferous. The line is described by Leverett[8] from the Genesee Valley to southern Ohio and is clearly traceable on all the United States Geological Survey topographic sheets along its course, separating the typical dissected plateau on the south and east from lake flats and rolling plains on the north and west. South of lat. 40° 30′ the line lies near the edge of the glacial drift but the thin edge of the latter generally overlaps the plateau, its edge almost following the western limit of the Pennsylvanian Coal Measures. It seems best on the whole, however, to follow the line of the topographic break a little farther west, since neither the edge of the Coal Measures nor that of the drift could be followed far either north or south.

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[7] Fairchild, H. L. N. Y. State Ed. Dept. Bull. 519.

[8] Leverett, Frank. Glaciation in the Erie and Ohio Basins. U. S. Geol. Surv. Mon. 41, p. 67.

From Chillicothe, O. (lat. 39° 15′) southward, the topographic break agrees essentially with the Carboniferous-Devonian contact and this line is followed to Kentucky River. At that place the western edge of the Carboniferous is also essentially the western edge of the Coal Measures. North of that point the topography on the narrow strip of Lower Carboniferous is not materially different from that of the Coal Measures on the east. South of that point the western edge of the Coal Measures is marked by an increasingly bold escarpment which separates the Cumberland plateau (Pennsylvanian) from the Highland Rim (Mississippian). The province boundary follows this contact southwest and then west to the boundary of the Coastal Plain, that is, to the landward margin of the Cretaceous near the state line between Mississippi and Alabama.

In Alabama the Plateau province borders the Coastal Plain along the Carboniferous-Cretaceous contact. This line is ragged and indefinite and is marked by no abrupt change in elevation or topography. On the plateau side (northeast) the Cretaceous appears in isolated patches capping hills and uplands. These should be allotted to the plateau. On the side of the Coastal Plain the Carboniferous appears only in stream valleys. Such should be counted in the Coastal Plain. The transition belt is thus narrowed to a few miles. Within this zone are many points where the contrast is sharp, being expressed in topography, or soils or in both.

INTERIOR LOW PLATEAU.—The name Interior Low Plateau is proposed as a substitute for Hayes's "Interior Lowlands."[9] The change is made because the term lowlands is properly applied only to several subdivisions, the smaller part, of the province. The rest is typical dissected plateau, even though in the western part the uplands and divides have an altitude of only about 500 feet. The altitude on the eastern side is about 1,200 feet. Here it is known (in Tennessee) as the Highland Rim, but the country thus designated grades without a break into that of southern Indiana and Illinois and western Kentucky and its essential character (dissected plateau) is continuous, even though summit levels decline gradually to about 500 feet. Within this area are two basins (the Nashville and the Blue Grass) which should be recognized as natural divisions of a lower rank.

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[9] Hayes, C. W. Physiography of the Chattanooga District, XIX Ann. Rep. U. S. Geol. Surv.

The boundaries proposed for this Interior Low Plateau are as follows: Beginning in southern Ohio where the edge of the glacial drift intersects the western edge of the Carboniferous rocks, follow south along this western edge of the Carboniferous to Kentucky River. South of Kentucky River the boundary between the Low Plateau and the Cumberland Plateau is the escarpment at the western edge of the Coal Measures. This line is a bold one in Tennessee; less bold but still adequate in Kentucky and Alabama. Stream erosion has made it very irregular. In the mapping of large areas it is necessarily generalized.

On its western side this province borders the Coastal Plain, the line being the Paleozoic-Cretaceous contact. Follow this contact northward to the Ohio, using for practical purposes the course of Tennessee River. Follow the same contact west through southern Illinois to the Mississippi.

Northward from the point thus reached to the edge of the glacial drift, the Mississippi is taken as the arbitrary boundary between the Ozark Region and the Interior Low Plateau. Eastward from the Mississippi the edge of the glacial drift constitutes the boundary between the Forest Plains on the north and the Interior Low Plateau on the south.[10] Its general course is eastward to the Allegheny Plateau. East of Louisville it does not deviate much from the course of Ohio River but west of that it bends far northward around southern Indiana which has a topography like that of Kentucky west of the Blue Grass Basin. The edge of the drift is not a sharply marked line. Locally the drift thins out gradually throughout a zone of twenty miles or more.

The two subprovinces within the Interior Low Plateau comprise the areas of rock older than Carboniferous. The edge of the latter forms an escarpment, locally frayed and irregular, entirely around the Nashville basin and around the Blue Grass basin on the east and south. Throughout practically its entire extent this escarpment is plainly visible as a range of hills, when viewed from the basin floor. The northern and northwestern boundary of the Blue Grass Region is the edge of the Glacial drift, that is, the outer boundary of the province.

THE NEW ENGLAND REGION.—The New England-Adirondack province is an area of complex history and features. Parts of it correspond with more or less exactness to the several provinces of the Appalachian belt. From a geological standpoint it is often convenient to treat the New England area and the Appalachians together. Even in this view, however, there are important differences, and from the standpoint of present day geography the differences are even more important.

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[10] See Leverett's map, U. S. Geol. Surv. Mon. 38, Pl. VI.

With respect to elevation this region falls naturally into three divisions. These are (1) The New England province or sub-province, (2) The Hudson-Champlain valley and (3) The Adirondacks.

The New England division includes the plateau and mountain country east of the Hudson-Champlain valley. It is difficult to define in geological terms in such a manner as to distinguish it from that which lies to the west. The line which separates it from the latter follows no one geological contact and for much of the distance no contact at all. From the Canadian Boundary south to near Rutland, Vt., the contact of the Pre-Cambrian on the east with the Cambro-Ordovician on the west is marked by a distinct contrast between mountain topography on the former and lowland on the latter. Southward from about ten miles north of Rutland a belt of metamorphosed Paleozoic rocks lying west of the Pre-Cambrian, has almost as rugged topography as the latter. This is the Taconic belt. If the New England province is to be distinguished from the Hudson-Champlain valley by anything more than geologic history, this rugged country on the metamorphic rocks must be classed with the province on the east. The boundary between the Taconic belt and the valley lands on the west is locally sharp but is often represented by a transitional belt. Toward the south, this belt on the metamorphic rocks is itself distinguished in topography from the older eastern belt, but on the whole it appears that if a more restricted New England province is to be distinguished geographically from the Hudson-Champlain valley, the former must include the Taconic belt.

The Hudson-Champlain valley is, with respect to elevation, a continuation of the Appalachian Valley and it was carved out at essentially the same time, its location and extent being determined by weaker rocks as in the case of the Appalachian Valley. On the other hand there are differences between these two valleys which must be recognized even in a general description. (1) The folding which affected the southern trough and is an essential condition of its peculiar features, practically dies out in southern New York. Any close folding farther north is of very different age, mid-Paleozoic instead of post-Paleozoic and belongs to the mountainous country on the east. Hence these valleys differ in history. (2) The folding in the northern belt was not, as in the southern belt, such as to cause parallel outcrops of strong beds alternating with weak and thereby (in the second erosion cycle) parallel flat-topped ridges. In so far as the folding was of this character it belongs to the region farther east where metamorphism was so severe as to cause a different style of topography. (3) Since the metamorphosed rocks of New England grade into the unchanged sediments of the Hudson Valley, the latter is less clearly delimited than the Appalachian Valley to the south. (4) The Hudson-Champlain Valley owes many of its surface features to glaciation.

These considerations make it necessary in treatment, and desirable in mapping, to separate the northern valley from the southern. This should be done without failure to emphasize the continuity of the valley. The northern part should be separated from the southern by a line arbitrarily chosen; it may be at the Hudson or at the divide between the Hudson and Delaware systems which nearly agrees with the New York-New Jersey boundary; or it may be at the edge of the Glacial drift which nearly agrees with the New Jersey-Pennsylvania boundary. The other boundaries of the Hudson-Champlain trough are given in the definition of adjacent provinces.

It is a matter of taste whether the Hudson-Champlain Valley shall be considered a sub-province of an elongated Appalachian Valley or of a New England-Adirondack Region. It is allied to both and distinguished from both. According to the nature of the discussion it may be considered sometimes with the one; sometimes with the other. When the discussion has to do with geography rather than geology it will naturally be counted with the New England-Adirondack province, whose climate it shares, as it also shares in human history and cultural features.

The Hudson valley includes the valley of the Mohawk with which it is a unit geographically, structurally and topographically. The Mohawk Valley is in turn perfectly continuous with the Lake Province from which it must be arbitrarily delimited. The line here chosen is the Mohawk-Ontario divide. This is considered better than to include the Mohawk Valley with the Lake Province and separate it arbitrarily from the Hudson Valley. To do the latter would require a line which is absolutely arbitrary, not based on structure, topography or even drainage and decidedly longer than the Mohawk-Ontario divide.

The Adirondack province or sub-province is essentially the area of pre-Cambrian rocks in Northern New York. The greater part of the circumference of this area is marked by a topographic break. It is convenient and satisfactory both geologically and geographically to adopt the lower contact of the Paleozoic as the boundary of this province. The country within this line is one of subdued mountains, strongly glaciated. Outside the boundary, are nearly horizontal strata, generally weak and reduced to lowlands of small relief. An exception is seen on the west side of the mountain area, where the pre-Cambrian rocks are worn down to a lower level and smaller relief and the strata resting on them rise locally to a higher level than that of the Adirondack province.

The Lake Region.—Powell in his Physiographic Regions of the United States[11] recognized a province which he called the "Lake Plains." To him it was characterized by the presence of many lakes and a broad extent of old lake bottoms and terraces. By implication also it was distinguished by its forest cover because the adjacent province on the south and west was characterized as prairie.

It must be apparent that in any physical description of the United States there is one region in which the most characteristic features are due to recent glaciation. The explanation of all features in this region is so intimately related to glacial history that this history becomes the dominant theme in the discussion. The adjacent provinces on the south and west were also glaciated but the types of topography produced in them differ less from the non-glacial types. The geographic difference between the glaciated prairies of eastern Nebraska and the unglaciated prairies of eastern Kansas is small compared with the difference between the till plains south of the Wabash and the morainic, marshy and lake-dotted area across the river.

There is no very simple definition of this province which gives it a logical unity and clearly distinguishes it from its neighbors at all points. In any case Powell's boundaries need refining and some alteration; but no other division of the north central United States has yet been proposed which approaches Powell's in geographic significance. Provinces based on the structure and distribution of the ancient underlying rocks have been suggested. Forms and relations have been pointed out which are interesting from the standpoint of theoretical and historical physiography but which have relatively small value to the present physiography and geography of a country covered with glacial drift from 8 to 800 feet thick. Powell's division implied that in such a country the features determined by the recent ice invasion are of greater importance than those which depend on a pre-glacial surface of no very great relief. Whether the criterion of distinction be simple or complex, expressible in few words or many, the fact is plainly recognizable by all that in approaching the Great Lakes from any side in the United States a distinct group of features is encountered and a more or less distinct line crossed. This is true whether the lake region be approached from the Allegheny Plateau, the forest plains of Ohio and Indiana or the prairies farther west. The reality of this contrast does not depend on any one's ability to express it in neat formula.

The central fact about this lake province is that it is a forested region with a topography due to recent glaciation. Its neighbor provinces in the United States are contrasted with it in topography or in climate, the latter contrast being important only at the northwest where it expresses itself in a somewhat abrupt transition from forest to prairie; and even here the contrast between forest and prairie is not the only factor in locating the boundary. In the topographic contrast, glacial plains are not included in the lake province even where forested. This may not be very logical but the lake province would lose its distinctive character if they were included. They lie largely in the prairie province and even where forested they are quite unlike the other characteristic features of a recently glaciated country.

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[11] Powell, J. W., Nat. Geogr. Mon. No. 3, 1896.

The three types of topography which are characteristic of the Lake Region are lacustrine plains, swamps and moraines. An examination of the boundaries suggested will reveal the fact that there are few places where a contrast of land surfaces on its two sides is wanting or where the transition zone exceeds a few miles.

In western New York the lake province is bounded on the south by the Allegheny Plateau. The boundary line has been traced empirically on the United States Geological Survey topographic sheets and is fairly definite. It so nearly agrees with the Onondaga and Helderberg outcrops east of the Finger Lakes and with the outcrop of the Portage sandstone west of those lakes that the line thus defined may be used.[12] The same line is essentially the southern shore of Pleistocene lake waters when they first extended uninterruptedly from the Erie Basin to the Mohawk. For detailed work, plotting statistics etc., or treating the physiography of a county, the boundary line should follow as nearly as possible the actual break in topography. Old lake bottoms and outcrops of strata are matters of *interpretation* only, and furnish good arbitrary lines where a clear topographic break is wanting.

West of the meridian of Buffalo the scarp which clearly limits the lake plains on the south is evidently due to stream and wave erosion. It does not follow the outcrop of any one formation but crosses the outcrops in succession from the Portage to the Pennsylvanian. Its distance from the lake shore in western New York and Pennsylvania is from two to ten miles. In northeastern Ohio, in the basin of Grand River, a long tongue of the lake shore lowland extends forty miles south to beyond Warren. Westward from this detour the escarpment again runs parallel to the Erie shore as far as Cleveland. West of that place the boundary of the Allegheny Plateau turns to the southwest and the southern boundary of the lake province lies against the Forest Plains. The latter consist of glacial till plains, while the Lake Province in this part consists of the former bottoms of Pleistocene lakes. The old beach line of Lake Maumee is taken as the boundary.

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[12] Cf. Leverett U. S. Geol. Surv. Mon 41, p. 67.

This is the nature of the province boundary as far as Fort Wayne, at the western extremity of glacial Lake Maumee.

West of Fort Wayne the lake province is characterized by morainic topography and many small lakes, and in northwestern Indiana by the great Kankakee swamps in addition to these. The southern limit of these characteristic features of the Lake Province is everywhere so near the Wabash River that it is well to use that river as the province boundary from Fort Wayne to Williamsport, Ind.[13] South of the Wabash are the typical till plains which extend east into Ohio and west into Illinois. From Williamsport, Ind., the province boundary goes northwest along the morainic ridges which enclose the Kankakee swamp (Saginaw glacial lobe—Late Wisconsin epoch), and follows the outer edge of the Valparaiso moraine into Wisconsin. Across that state the line follows the outer edge of the strong terminal moraine which borders the Wisconsin drift sheet.[14] For a large part of this distance this line separates a topography of morainic character with abundant lakes, from one of relatively low relief on the older drift which is nearly free from lakes. Elsewhere the border of the lake province lies against the Driftless Area which, with its erosion topography, is even more strongly contrasted with the Lake Province than is the older drift.

For about forty miles in Central Wisconsin the line here traced separates the terminal moraine from a country not overridden by the ice but partially buried beneath outwash deposits (known to many as the "Camp Douglas country"). With its deep surficial deposits of sand, its poor drainage and scattered coniferous forest, this country has perhaps more in common with the Lake Province (which is also locally very sandy) than with the Driftless Area with which it is otherwise classed. This alternative should be considered.

Crossing Minnesota from near St. Paul to near Lake Traverse near the source of Red River, is a transitional zone separating surfaces of very different aspect. The valley of Minnesota River on the south is relatively smooth, low, free from lakes and unforested. The country on the north is forested, abounds in lakes, is higher and rougher. The three boundary lines here suggested (edge of forest, edge of lake-dotted area and edge of the higher land) are rarely apart more than the width of a county. The combined effect of these three contrasts is to give to the country north of the line a very different aspect from that to the south.

Aside from the contrast of forest and prairie, which is due chiefly to climate, the location of this province boundary across southern Minnesota is controlled primarily by a strong interlobate moraine of the late Wisconsin glacial epoch. This group of ridges of terminal moraine was built by the combined action of the Superior glacier from the northeast and the Minnesota-Des Moines lobe moving southeastward. The other terminal moraines of the latter lobe lie to the south and west, partly in Minnesota and partly in Iowa and the Dakotas. The topography on these moraines is locally similar to that on the interlobate moraine which is here assigned to the Lake province, but taking into account their distinctly prairie aspect and their isolation (being separated from the forested moraine by the relatively smooth and low valley of Minnesota River) their inclusion in the province known distinctively as the Lake Region would destroy its unity. Those familiar with northern Iowa and the Dakotas will generally agree that if a prairie province is recognized at all it should include the morainic tracts in these states which, if topography alone were considered and continuity disregarded, would be more closely related to the Lake Province.

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[13] Dryer, Studies in Indiana Geography.

[14] For convenience use Pl. II, Atlas of the Wis. Geol. Survey, 1881.

From a point east of Lake Traverse the province boundary runs almost due north into Canada. Like the line through southern Minnesota, it has been located empirically on the county geological maps[15] by following the edge of the morainic and lake-dotted country. Comparison with the forest map[16] shows that the same line is essentially the edge of the forest. The line follows very close to the most prominent beach of glacial Lake Agassiz (generally the Campbell beach). As this is the most definite criterion mentioned it should be adopted as the conventional boundary.

OZARK-OUACHITA REGION.—The Ozark-Ouachita province is a plateau and mountain region surrounded by plains. In its complexity it is comparable with the entire group of Appalachian provinces. The only reason for treating the former as one province while separating the latter, is its smaller size and the desire to avoid multiplicity. For more detailed treatment, it is divided into sub-provinces. The whole has a certain unity, however, supplied by its elevation and ruggedness as compared with neighboring areas.

The most clearly marked boundary is on the southeast where this province is separated from the Coastal Plain by a distinct topographic break extending from Cape Girardeau on the Mississippi to southwestern Arkansas. Through a part of this distance a scarp may be seen from the St. Louis, Iron Mt. and Southern Railway which follows the inner edge of the Coastal Plain generally five to fifteen miles from the boundary. The scarp marks the contact of Paleozoic Rocks with Tertiary. The line of contact should be taken as the province boundary.

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[15] Atlas of the Minn. Geol. Survey, 1901.

[16] Minn. Geol. Survey, Vol. I.

Northward from Cape Girardeau the contrast between the Ozark province on the west and the prairie plains on the east is based on elevation and topography (themselves due to structure, the strata of the Ozark province being domed). The contrast is not sharp. The Mississippi follows roughly the edge of the dome and may be arbitrarily taken as the province boundary as far north as the mouth of Meramec River near St. Louis. In a similar manner the Missouri may be arbitrarily taken as the northern boundary, but it is best to exclude from the Ozark province the area of Carboniferous rocks lying west of the Mississippi and south of the Missouri near the mouth of the latter. This inter-stream area (St. Louis and vicinity) should be assigned to the Prairie province not only because of its character but because it is desirable to avoid irregular and semi-detached extensions to provinces.

Sharper topographic contrasts both on the north and on the east might perhaps be found by following certain geologic lines as is done elsewhere, but such lines would be more irregular than the rivers. Moreover these rivers are everywhere county or state boundaries which afford a great advantage in reducing statistics to a province basis.

The western boundary of this province is least definite but the contact between Lower and Upper Carboniferous rocks has already been used for a part of the distance.[17] Some of the distinctive Ozark features are associated with the Lower Carboniferous rocks and there is a similar association of the Upper Carboniferous with the Prairie province; hence it seems best to follow this contact as far as possible. Through much of its extent it is followed by small streams which may, without serious inaccuracy, be substituted for the actual line of contact in locating the boundary. In this way after leaving the Missouri River, Blackwater Creek might be followed and, after an interval, Osage River, Sac River and Cedar Creek in turn, and, still farther south, Spring and Neosho rivers. The line is thus carried south to the Arkansas river at Muskogee, Okla. Thence southward it has been located by Taff[18] between the folded rocks and low level-crested ridges of the Arkansas Valley on the one hand, and the nearly horizontal beds on the other, which occasion the benches and low scarps of the prairie province. The Lehigh Basin[19] falls naturally in the Arkansas Valley sub-province.

The Arbuckle Mountains constitute a western extension of this province. The province boundary surrounds them in such a manner as to include all strata older than Devonian.[20] The southern boundary is the edge of the overlying Cretaceous beds. The same line, continued eastward, separates the Prairie province on the south from the Ouachita Mountains.

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[17] Adams, Geo. I, U. S. Geol. Surv., 22d Ann. Rep., Pt. II, p. 69.

[18] Taff, Joseph A., Atlas U. S. Geol. Surv., Tishomings Folio No. 98, p. 1, 1903.

[19] See Coalgate and Atoka folios.

[20] Taff, Joseph A., U. S. Geol. Surv. Prof. Pap. 31, p. 13.

The Arbuckle Mountains are not a continuation of the Ouachita range but an outlying group, separated from the Ouachita by a southwesterly extension of the Arkansas Valley sub-province. This extension of the valley sub-province is not a part of the Arkansas drainage basin but is structurally and topographically similar.

The line which separates the Arkansas valley sub-province from the Ozark dome on the north is necessarily arbitrary, being located at the assumed foot of the Boston Mountains, a dissected plateau declining southward with the dip of certain hard strata. The southern boundary of the Arkansas Valley is drawn as nearly as possible where the gentle folding and low monoclinal ridges of this sub-province give way to the close folding and distinctly Appalachian topography of the Ouachita Mountains. The lines here used are taken from Adams.[21]

CENTRAL LOW PLAINS.—An irregularly shaped region stretching north, south and east from the central United States is essentially a low plain. It is in the main bounded by lands which are either not low or not plains. Locally the adjoining regions are also low plains but of different origin and more closely allied with other extensive regions.

This large province is capable of much subdivision and several of the subdivisions are so strongly characterized as to deserve consideration as independent provinces. If desired, the glaciated prairies may thus be distinguished from the unglaciated and especially the Driftless Area of the upper Mississippi Valley.

The Forested Glacial Plains comprise that part of the Central Low Plains which lies in Ohio, Indiana and southern Illinois. Almost everywhere its surface is a glacial plain. There are some morainic ridges but they are relatively narrow and low and without lakes and have gentle slopes. Only in the vicinity of the large streams has this plain been dissected into hills. The boundaries of this province, except on the west, have already been traced. To the south lies the Interior Low Plateau, driftless and everywhere dissected; to the east, the Allegheny Plateau, likewise dissected. The smallest topographic contrast is in northern Ohio, where the beach of Glacial Lake Maumee separates the Forested Glacial Plains from the old Pleistocene lake bottoms which belong to the Lake Province.

A line curving to the south and west from Lafayette, Ind., to the mouth of Missouri River is indicated on the Forest Service map of the United States as separating forests from prairies. This boundary is necessarily indefinite and at no other place has the mere edge of the forest, taken alone, been used as a major province boundary; hence it is probably best to treat the forest plains thus cut off as a sub-province rather than a province. Forests at one time covered probably seven-eighths of the division here classed as Forest Plains.

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[21] Adams, Geo. I., *loc. cit.*

A small but strongly characterized subdivision of the Central Low Plains is the Driftless Area of southwestern Wisconsin and adjacent states. It is difficult to choose a name for the great central province (here called Central Low Plains) which can with propriety be made to cover this subdivision and the Forested Glacial Plains just described. In all but the most general descriptions of very large areas, this Driftless Area must receive separate treatment. It is here included in the Central Low Plains merely to avoid multiplicity, as smaller odds and ends have elsewhere been thrown into adjacent provinces.

The essential fact about this area is its dissected plateau character. Its topography is not unlike that of western Kentucky. In a part of this area adjacent to the moraines of the Lake Province the valleys have been filled by outwash, making plains of such wide extent that the hilltops rise above them as isolated buttes. The propriety of treating this area as a part of the Lake Province has already been considered.

For convenience in generalization the sub-province boundary line on the accompanying map follows that of Chamberlin and Salisbury in the Sixth Annual Report of the Director of the U. S. Geological Survey. Parts of the boundary have since been mapped in greater detail.

The line between the glaciated and the unglaciated prairies farther west is less distinct than might be supposed. The drift north of the line is very old, not very thick, is deeply covered with loess and has a mild relief. On a similar topography south of the line there is a thick soil partly of loessial origin and not very different from that to the north. The rather indefinite edge of the drift is near Kansas River.

The Black and Grand Prairies on the Cretaceous rocks of north central Texas constitute a subdivision which may well be distinguished as such from the deeply denuded Carboniferous and Permian prairies to the west. The former differ not only climatically but in topographic history, in details of topography and in character of soil. The Black and Grand Prairies are quite as closely related to the Coastal Plain on the east as to the Prairie Plains on the west. Custom, however, favors their inclusion in the Prairie Province and not in the Coastal Plain. (See also *Coastal Plain,* above.)

In choosing a line which shall separate the Prairie Province from the Great Plains, it is desirable to conform to popular usage in so far as consistency in such usage can be found. At the same time it is desirable to draw the line by some logical criterion; otherwise the provinces thus outlined will lack unity. It is of course highly desirable that the line should correspond to something visible in the field. The line here proposed represents everywhere, except in Nebraska and locally in Kansas, an eastward facing escarpment. The surface on the east is relatively low and mildly rolling. In part this lower level and milder surface on the east may be the work of a later cycle of erosion; in part it is due to the presence of weaker rocks. The surface immediately to the west is a few hundred feet higher and generally rugged. It is the eastward frayed edge of that which farther west is a broad and generally smooth plateau.

Beginning in North Dakota, the Plateau of the Missouri (not the Missouri Coteau but the plateau on which the latter rests), terminates on the east, or northeast, in an escarpment 300 to 400 feet high. Through most of its length of more than 300 miles in North Dakota, railroads follow the foot of this escarpment. On one side of the line lie the fertile prairies of North Dakota, adapted to farming. On the other, above and beyond the escarpment, the high grazing lands of the Altamont moraine, the real Coteau of the Missouri. The line here used is taken from Willard's Soil Map of North Dakota (1909) and follows the lower (eastern) margin of the strip designated as the sloping edge of the Missouri plateau. The topographic break is shown very clearly on the Edgeley and adjacent topographic sheets of the United States Geological Survey. Continuing southward into South Dakota, the line becomes less clear. It is nowhere far from the Missouri-James divide.

In Nebraska alone, the line is almost wholly arbitrary. Between typical low Prairie and typical Great Plain there is complete gradation with no abrupt change of altitude or style of topography. Neither bed rocks nor glacial drift are topographic factors of importance, for both are buried by loess thirty to sixty feet deep. However, since the line in the Dakotas is plain and a similar line in northern Kansas equally plain, and the edge of the glacial drift in Nebraska (so far as determined)[22] is essentially in line with the escarpments in South Dakota and Kansas, this line, the edge of the glacial drift, is taken as the arbitrary boundary in Nebraska.

In Kansas the outcrop of the Dakota sandstone forms a rugged belt known as the Smoky Hills in the north, reaching from the Nebraska line almost to Arkansas River. This line of the Smoky Hills, the eastern eroded margin of a highland which is continuous toward the west, is the natural western boundary of the Prairie Province.

The eastern margin of the hilly belt is, of course, frayed and irregular, but forms a typical natural boundary between contrasted topographic types from the Nebraska line southward to the center of

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[22] See Todd, U. S. Geol. Surv. Bull. 158, Pl. 1; also Science, Feb. 20, 1914.

Kansas; that is, to a point not far west of McPherson. Fifty miles straight south of this point a similar contrast is found, the low plain on the east being uninterrupted, though its altitude declines southward. On the west is a dissected upland called the "Red Hills," its substructure being of the Permian "Red Beds." The ragged escarpment is 300 to 400 feet high. With diminishing dissection toward the west, and increasing remnants of the Tertiary cover, the "Red Hills" merge into the High Plains. As a province boundary their foot is entirely satisfactory.

South of Kansas the Red Hills escarpment is known (for reasons implied in the name) as the Gypsum Hills escarpment. In general it is the dissected edge of a western upland overlooking to the eastward the prairies of small relief which lie too near their local baselevel to be sharply dissected. In its southern extension this line lies very close to the boundary of the distinctively Great Plains flora, as mapped by Hill in his Physical Geography of the Texas Region.

The break of fifty miles in Kansas, alluded to above, is due to a westward extension of prairie plains along the Arkansas River, known as the Great Bend Lowland.[23] It is a smooth surface rising to the westward and is quite as high on any one meridian as the crests of the Smoky Hills upland on the north and the Red Hills upland on the south. It is not a lowland in the sense of lying near sea level, being 1,500 feet high on the east and rising steadily to 2,300 feet on the west. Neither is it low by comparison with its neighbors north and south. It is a lowland only in the sense of being near to its own local baselevel, for the Arkansas River has been unable to entrench itself here, probably because of the strong rocks crossed farther east. The parallel streams on the north and south have cut their channels from 100 to 300 feet lower on the same meridians. Their tributaries have therefore dissected into "Smoky Hills" and "Red Hills,"—the plateau which here remains as the "Great Bend Lowland."

This level prairie, being agriculturally favored, is commonly thought of as an arm of the prairie province extending into the Great Plains, but its topography and geologic history are those of the Great Plains. (See below under that subject.) Indeed all but a narrow strip along the river is an eastward peninsula of the High Plains, the central division of the Great Plains, having been here saved from erosion by the disadvantage of the stream which drains the area.

Whether this "Great Bend Lowland" be included in the Central Low Plains or in the Great Plains, there are difficulties in drawing the boundary. On the whole it seems best to include it in the Great Plains where it naturally belongs by reason of its geologic and physiographic history. Otherwise, arbitrary boundaries on the north and south must be selected. Its separation from the Low Plains on the east must also be by an arbitrary line. However, if the two free ends of the well established boundary be connected by a straight line across the fifty-mile gap in southern Kansas, the resulting line will not be far from the eastern edge of the Cretaceous and Tertiary rocks, both highly characteristic of the Great Plains. The line on the accompanying map is arbitrarily swung somewhat to the west.

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[23] Adams, Geo. I.—Physiographic Divisions of Kansas; Bull. Amer. Geogr. Soc., Vol. XXXIV, pp. 89-104.

It is worthy of note also, that even from an agricultural point of view the western end of this Great Bend Lowland differs quite as much from the typical prairies as the eastern end does from the border of the Great Plains.[24]

East of the meridian of 97° W. Long., and entirely surrounded by typical prairie of the Central Low Plains, is a north-south belt called the "Flint Hills," extending from northern Oklahoma northward about halfway across the state of Kansas. This belt has been described by Adams[25] as belonging to the Great Plains province. The character of the belt would justify this, but it is impossible to connect it with that province without including in the same boundary almost an equal area of the most typical prairie country. It seems better to describe the Flint Hills as a local feature, as must be done for the Ouachita Mountains in Oklahoma, the Turtle Mountains in North Dakota and many other exceptional features.

It is thus seen that throughout the six states traversed by the Great Plains-Prairie boundary line, the line in four of these and a part of the fifth (Kansas) is satisfactory. It has geological significance, conforms to popular usage and is marked by a topographic contrast within a narrow belt. The satisfactory character of three-fourths of the entire line justifies the somewhat arbitrary character of the remaining fourth. The actual drawing of the line is capable of further refinement.

THE GREAT PLAINS.—Between the Rocky Mountains and the Central Low Plains lies a great eastward sloping plateau. The name Great Plains is so firmly attached to this region by custom that it must be retained; particularly since it has been shown that throughout the greater part of its length this region is separated by a natural line (for the most part a dissected escarpment) from the region on the east which by comparison may well be called the Central Low Plains.

The unity of this large region consists in its plateau character. In this respect it is sharply distinguished from the mountains on the west and for the most part satisfactorily delimited from the low plains on the east. It is conceded to be impossible to distinguish plateau from low plains on the basis of mere elevation above sea level. The characteristics are always more or less relative, but the underlying thought is that a plateau, if not already dissected, lies high enough above baselevel to *admit of* sharp dissection while a low plain does not. The *principle* is quickly stated and consciously or unconsciously underlies our distinctions; to give an exact *rule* may be impossible. This is the principle carried in mind in determining the boundary between the Central Low Plains and the Great Plains.

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[24] See Report of Thirteenth Census, Vol. VI, p. 554, map.

[25] Adams, Geo. I., *loc. cit.*

It is unnecessary to describe in detail the boundary line between the Great Plains and the mountains on the west. If drawn in the field by various observers the several lines selected would nowhere be apart more than a few miles. For most of the distance the boundary is essentially at the contact of Mesozoic and younger rocks on the east with Paleozoic and older rocks on the west. At the immediate foot of the mountains these younger rocks are generally upturned, the harder strata forming foothills of the hogback type. Generally the first prominent hogback encountered in approaching the mountains should be taken as the boundary. Where such foothills are not present, as in the Lewis Mountains in northern Montana, and locally in the Big Horn of Wyoming and the Sangre de Christo of Colorado, the rise from the plain is generally so abrupt that the boundary may be drawn with sufficient accuracy on the United States Geological Survey contour map of the United States. (Scale 40 miles to 1 inch.)

The criterion here given suffices for the drawing of the line southward from the Canadian boundary at the foot of the Lewis Mountains, and eastward to surround the Big Belt and Little Belt mountains in Montana. South of these the line swings fifty miles westward to the Bridger Range on the 111th meridian, then again eastward at the northern base of the Bowlder and Beartooth plateaus which border Yellowstone Park on the north. Thus a great embayment is formed in the mountain front. In the center of this embayment stand the Crazy Mountains, an isolated mass similar to other volcanic centers on the Great Plains. These are separated from the Rocky Mountains on the north, south and west by a valley fifteen to twenty miles wide which is in every respect a continuation of the Great Plains except that from every part of it mountains are visible on both sides. It is a matter of taste whether the Crazy Mountains and this semi-circular valley be included in the mountain province or in the Great Plains. Whichever is done the practice should be uniform. In the accompanying map the more westerly line is used, which limits the mountain province more strictly, but the outer line is suggested as an alternative.

In a similar manner, after skirting the Beartooth Plateau, the province boundary may surround the Big Horn basin, thus classing it with the Great Plains, or the line may cut arbitrarily across the mouth of the basin (forty miles) to the end of the Big Horn Range. This would treat the Big Horn Basin as a feature of the mountain province, similar to some other basins smaller than this which are entirely enclosed by mountains. In using provinces as a basis for agricultural and other statistics it is essential that practice be uniform. On account of such usage, the longer and more detailed line is here favored.

From north to south along the foot of the Big Horn Mountains the line is determined both geologically and topographically within narrow limits. South of that for forty miles the Great Plains must be arbitrarily cut off from a similar plateau, the Central Rocky Mountain Basin. This arbitrary cut-off is inevitable, as it is impossible to treat southwestern Wyoming and northwestern Colorado as an extension of the Great Plains without great confusion in the use of names.

Along the Laramie Mountains of Wyoming, the Rocky Mountain Front Range in Colorado and the Wet Mountains south of the Arkansas River, there are few breaks in the line of hogback foothills. The line is thus well marked.

South and west of the Wet Mountains is Huerfano Park which has an uneven floor 7,000 to 9,000 feet above sea level. This park is partly cut off from the Plains by a line of igneous buttes. The line here used follows this line of buttes, leaving the park in the mountain province. The Spanish Peaks (volcanoes among the foothills) are assigned to the mountains and the line continues southward between the horizontal Laramie beds and the upturned older formations (Cretaceous and Carboniferous) on the west. Some uplands above 8,000 feet are thus assigned to the Great Plains province. The equally high Ocate Plateau (lavas) to the south is part of the same province, the line following, as before, the hogbacks of Cretaceous and Carboniferous rocks on the west of the volcanic plateau and south to latitude 35° 30′ where the Las Vegas Plateau (Cretaceous) comes to an end and overlooks the Pecos Valley (Triassic).

The Pecos valley, a highly characteristic portion of the Great Plains, is well delimited on the west by the Glorieta Mesa and the Mesa Jumanes, which are portions of the "Trans Pecos" Region. The boundary line (altitude 6,250 to 6,500 feet) is well shown on Hill's "Map of Texas and Parts of Adjoining Territories" accompanying his Physical Geography of the Texas Region.

Southward from the Mesa Jumanes the topographic break which limits the Pecos Valley on the west is easily traced at the foot of the following mountain ranges in the order named: the Jicarilla, Capitan and Sacramento ranges in New Mexico, and the Guadaloupe, Davis, Comanche, Caballos and Santiago ranges in Texas. This carries the boundary to the Rio Grande at longitude 102° 30′ West. North of this river to the Southern Pacific Railroad (about forty miles), the boundary is fairly indicated by San Francisco Creek (Rand-McNally atlas). The foot of the Jicarilla Mountains at the northern end of this line is essentially at 6,000 feet, but the altitude of the boundary declines somewhat uniformly to about 4,000 feet at the southern end. The exact plotting of this line awaits more detailed mapping but there is no question concerning its rank as a major province boundary.

For purposes of physiographic description and discussion the Great Plains province should be divided into three sections, northern, central and southern. Of these the central is best known and, for purposes of scientific treatment, its explanation holds the key to the other two. Its northern limit is the Pine Ridge Escarpment, a north-facing scarp locally 1,000 feet high, at the northern limit of the later Tertiary formations. It extends eastward from the north end of the Laramie Mountains in Wyoming through northwestern Nebraska and northeastward into South Dakota about fifty miles south of the Black Hills. Farther east it loses its sharpness. The line between the central and southern sections is essentially the Canadian River, which crosses the northern part of the Texas Panhandle.

The central Great Plains are again subdivided by north-south lines into three strips. The middle strip is well known as the High Plains. The western strip may be called the Dry Plains and the eastern one the Plains Border. This three-fold division is well recognized both popularly and scientifically. Only the names of the eastern and western strips are supplied. Alternative names are suggested below.

The subdivision of the Central Great Plains is based on physiographic history as follows: Consider these plains to have been a uniform smooth surface stretching from the mountains to eastern Nebraska and Kansas. The central strip or High Plains is what is left of this flat surface, still covered by the late Tertiary beds to which the flatness is due. The Plains Border on the east is the strip from which the Tertiary mantle has been eroded and which is now dissected but not reduced to the low relief which characterizes the Prairie province. It is in general a hilly country. The climate in this strip is slightly more humid than in the High Plains and the headwaters of east-flowing streams are pushing westward and broadening the Plains Border at the expense of the High Plains. The strip of Dry Plains on the west has likewise lost much of its Tertiary cover and all of its original flatness, but for a different reason. Here the climate is drier than on the High Plains and the grasses which grow here afford poor protection against erosion, as compared with the closely matted sods of the High Plains.[26] These three subdivisions may therefore be regarded as (1) a strip of *residual plain* in the middle (2) a strip of *denuded plains* on the west and (3) a strip of *dissected plains* on the east. The western strip (Dry Plains) includes a strongly marked subdivision shown on the accompanying map in northeastern New Mexico and southern Colorado. It is characterized by high mesas (in part lava flows) cut by deep canyons; elsewhere by isolated buttes (chiefly volcanic) rising above the general level of the Dry Plains. The southern edge of this subdivision is a south-facing escarpment overlooking the Canadian and Pecos valleys.

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[26] Johnson, Willard D.—The High Plains and their Utilization, 21st Ann. Rep. U. S. Geol. Surv., Part IV, 1900.

The northern section of the Great Plains (north of the Pine Ridge escarpment) can best be described in terms of the central section. It is a continuation of the denuded strip (Dry Plains) and the dissected strip (Plains Border) but lacks the High Plains, and the other two strips are not here separable. The High Plains stop at the Pine Ridge escarpment. How far they may once have extended north is not essential to our present purpose, but the Northern Great Plains have been much more profoundly denuded than any portion of the central section.

The southern section of the Great Plains has again three strips analogous to those of the Central section but somewhat differently developed. The High Plains of the central section are a group of patches, some large, some small. It is scarcely practicable to draw a line to enclose these remnants and outline the central High Plains. The best possible impression is gained from the map published as the frontispiece to the paper above cited.[27] South of the Canadian River, stretches the broad undivided table land of the Llano Estacado in western Texas north of latitude 32°. Farther south this central table land, here known as Edwards Plateau, has lost whatever of Tertiary mantle it may once have had and its surface is less flat. The substructure of the plateau is here a thick, resistant, horizontal limestone. The western strip of the southern Great Plains, unlike the corresponding strip farther north, is a great longitudinal valley (that of Pecos River) overlooked by a scarp 500 to 700 feet high, the western edge of the High Plains. Its ragged eastern margin, the Plains Border, is similar to the same feature farther north.

CENTRAL TEXAS HILL COUNTRY.—There is a large area in Central Texas which, for a want of a better name, may be called the Central Texas Hill Country. The name is not satisfactory and its boundaries are not sharp; but it can not be included in either of the neighboring provinces without destroying their unity. It is not itself a unit in topography but comprises five or six subdivisions, each with its own individuality and needing separate treatment in any detailed account. The whole is, however, a dissected and partly denuded tract, bordered on the one hand by residual plateaus and on the other by relatively low plains. It is more advanced in its erosion cycle than the plateau on the west and south, and less advanced than the prairies on the north.

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[27] Johnson, Willard D., *loc. cit.*

Ignoring for the present the details of structure and history, it should be remembered that the whole of central Texas was once covered by a great eastward-sloping roof of early Cretaceous strata, the Edwards limestone. This was underlain for the most part by weaker rocks, but not everywhere. West and south of the center, this strong roof still persists in the Llano Estacado and the Edwards Plateau. To the east in the Grand Prairie the same formation is not deeply dissected because it has lain too near its baselevel. On the north, the same cover has been entirely stripped away from the locally baselevelled Permian prairies. Only in the center is the work of reducing the hard rocks but half done. We have therefore on the west and south, plateau *not yet* cut down; on the east, low plains *too low* to be much cut down; on the north, rolling prairie *already denuded;* in the center, a hill country *in process* of down cutting.

The above statement is necessarily the result of generalization. It is not to be expected that an area so defined should have clean cut boundaries. However, the contrast between this area and its neighbors is sufficiently sharp to have received expression in the language of the people. From this source Hill[28] has appropriated the names Burnet Country, Callahan Divide, Lampasas Country and others which are applied to subdivisions of this great area.

The western and southern portions of this Hill country are merely the local representatives of the dissected *Plains Border* as defined in outlining the central section of the Great Plains. The whole province might in fact be regarded as an expanded Plains Border; but to map this as a subdivision of the Great Plains would seem to be doing unnecessary violence to a name long in popular use. It was said above that the eastward dipping Edwards limestone constitutes the substructure of the lower-lying and hence less deeply dissected Grand Prairie on the east. Westward from the Grand Prairie the same formation rises to higher altitudes and is deeply dissected. This is Hill's "Lampasas Cut Plain," sustaining much the same relation to the Grand Prairie that the Plains Border does to the High Plains. Stretching westward from these "cut plains" to the still more rugged fringe of the Great Plains is a line of plateau remnants marking the "Callahan Divide," between the head waters of the Brazos on the north and those of the Colorado on the south. It is a rough country having the same history as the "cut plains" on the east and the "plains border" on the west but in a more advanced stage of erosion than either of these. North of this line of buttes and mesas are the prairie benches and east-facing escarpments of the denuded Permian, drained by the Brazos headwaters. To the south also, and hence within the province here outlined, the headwaters of the Colorado have reduced many areas to lower elevation and gentler relief.

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[28] **Hill, R. T.—U. S. Geol. Surv. Topographical Atlas, folio No. 3, 1900.**

Much of this area, while stripped of its former cover of Lower Cretaceous limestone, has not been reduced even approximately to its local baselevel because the rocks thus exposed are themselves resistant. This applies to the area of pre-Cambrian rocks in the southeast part of the province (Hill's " Burnet Country ") and to a strip of Carboniferous rocks west of the Cretaceous outcrop on the east side (Hill's " Palo Pinto Country "). These parts of the province are quite as rugged as the " Cut Plain " and the " Plains Border," with their partly destroyed cap of Edwards Limestone, but the *styles* of relief are very different.

On the south this province is not sharply separated from the Edwards Plateau. The latter is itself partly dissected, and progressively more so as its edges are approached. Where this fringe of dissected plateau terminates on the south in the Balcones Fault scarp it is clearly distinguished from the next province, but on the north it passes more gradually into the semi-denuded basin which is here styled the Central Texas Hill Country. The line of separation here used is essentially the edge of the Lower Cretaceous as shown on the geological map of the United States (U. S. Geol. Surv., 1911). The area of pre-Cambrian rocks, and that in which Lower Cretaceous outliers are found are assigned to the Central Texas Hill Country. The arbitrary line separating the Lampasas Cut Plain from the Grand Prairie is taken from Hill.[29]

THE NORTHERN AND WESTERN ROCKY MOUNTAINS.—This province embraces all contiguous mountains in the United States north and west of central Wyoming as far as Okanogan River in northern Washington. This river is the conventional boundary between the Cascade Mountains and the Northern Rocky Mountain province. The length of this conventional boundary in the United States is not over fifty miles. Throughout its remaining twenty-five hundred miles the boundary of this province is marked by a contrast of mountains on the one side and plateau on the other. For the greater part of this distance the contrast is sufficiently sharp to be visible in the field within a single view. The boundary line traced in this way is highly irregular. The province is not of compact shape but shows irregular projections. The advantage of drawing the boundary in this detailed way is that the line on the map corresponds to something visible in the field. The area within the line is all mountainous, the valleys being so narrow as to be plainly incidental to the mountain character. Greater compactness might be given to the province by generalizing the boundary line, but such compactness would exist only on the map and not in Nature.

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[29] Hill, R. T., *loc. cit.*

The province as thus outlined embraces twenty-five or more separate ranges and many important valleys, bearing distinct names and needing individual mention in any detailed treatment of the area. The ranges differ in topography, structure and physiographic history but all together form a continuous expanse of mountain country extending northward far into Canada. West and north of Yellowstone Park, the Madison and Yellowstone Rivers, with certain branches, occupy a trough which cuts entirely across the province with only a single pass higher than 6,000 feet. If it is desired to divide the province purely for convenience of treatment this line may be used.

The boundary between this province and the Great Plains on the east has already been traced in discussing the latter. At the south end of the Bighorn Mountains, where that range curves to the west under the name of Owl Creek Mountains, the province boundary nowhere departs very far from the contact of the Mesozoic and Tertiary rocks on the one hand and the older rocks on the other. Locally the boundary is marked by hogback foothills. The valley of Wind River is thus included in the plateau to which the name Central Rocky Mountain Basin is here applied. The Wind River Mountains form a long peninsula of the mountain province indenting the Central Basin. Around these, as elsewhere, the boundary line follows hogback ridges where present, and essentially the edge of the Tertiary rocks where such ridges are absent. In like manner the line is drawn at the east foot of the Salt River Range as far south as the forty-second parallel. South of that line these mountains dwindle in height and become scattered hills. The boundary line is therefore arbitrarily carried westward at this point to Bear Lake at the east foot of the Wasatch Range. By criteria named above, the line is drawn south from this lake, then eastward to surround the Uinta Range which overlooks the Central Rocky Mountain Basin to the north and the Colorado Plateau to the south. Continuing southward to Mount Nebo, at the southern extremity of the Wasatch Range, the line follows the base of the mountains to Salt Creek and Nephi. All rocks older than Mesozoic are plainly in the mountain province.

Going north at the west foot of the Wasatch, the province boundary is marked by a perfectly clear and abrupt topographic break separating the Wasatch Mountains from the Great Basin. This line is so drawn as to leave to the west all the Quaternary-filled basins, so highly characteristic of the Great Basin. It follows the valley of Bear River northward to lat. 42° 40′. Thence it continues almost straight north at the west foot of the Caribou Mountains, the Big Hole or

Snake River Mountains, and the plateau of Yellowstone Park. North of lat. 43° the mountain province is bounded on the west by the Snake River lava plateau. North of lat. 44° the province boundary separates two lava plateaus, the lower, nearly level and unforested Snake River plateau on the west and the higher, forested and rougher plateau of Yellowstone Park on the east. The line of division is approximately the 6,000 foot contour line.

Turning southwestward at this point with the 6,000 foot contour (U. S. Geol. Surv., 3-sheet map), the boundary line skirts the foot of the Bitter Root Mountains (if the name may be extended eastward so far). Farther west the line follows the foot of the Salmon River Mountains at an altitude of 5,000 to 6,000 feet. In a large way the line thus drawn is in striking agreement with the edge of the lava flows which constitute the surface of the plateau. These abut against the mountains of old Paleozoic and older intrusive rocks (U. S. Geol. Surv. Geological Map of North America). The line is of course irregular in detail.

The boundary line thus defined continues west to longitude 116° near Boise City, thence nearly north at the contact of the lava flows on the west with the ancient batholith which constitutes the Salmon River Mountains.

North of the 45th parallel, the nature of the line or zone which separates plateau on the west from mountains on the east is less clear. The northern end of the great batholith constitutes the Clearwater Mountains. Apparently their western front is bold though very irregular and indented by lava-filled bays. The whole country west of the great batholith seems to be composed in the main of horizontal beds and is therefore, however dissected, much more closely related to the plateau province than to the mountains. North of the Clearwater Mountains the Coeur D'Alene Mountains (46° 30′ to 47° 30′ N. lat.) seem to extend westward essentially to the edge of the lavas as indicated on the United States Geological Survey map. Spokane River is approximately on the province boundary from the city of Spokane to near its mouth. Beyond that the boundary trends westward on the north side of Columbia River, but details are not at hand to locate the line with exactness. There is a considerable area of plateau country north of the river but its limits are apparently not that of the Tertiary lavas shown on the geological map.

CENTRAL ROCKY MOUNTAIN BASIN.—The two mountain provinces, northern and southern Rockies, are not connected by any continuous range. On the other hand, a plateau surface is continuous from the Great Plains on the east to the Colorado Plateau on the west. South and west from Central Wyoming, this transverse plateau expands into a basin having an extreme length east and west of 300 miles and an extreme width of 200 miles. Single ranges from the mountain provinces project finger-like into this basin and some low isolated mountains rise from its plateau surface. These would be higher if not buried in part by younger horizontal beds.

The boundaries between this Central Rocky Mountain Basin and the northern mountain province have already been traced from the Bighorn Mountains to the Uintas. Its boundary against the southern mountain province is of the same character, equally clear, much of it abrupt and locally marked by foothills of the hogback type.

For a stretch of fifty miles at the northeast, this basin is continuous with the Great Plains and must be separated by an arbitrary line connecting the Bighorn Mountains of the northern province with the Laramie Hills of the southern. The line may follow the axis of an anticline but is not topographically marked.

In like manner, and for a somewhat longer distance, this province must be separated from the Colorado Plateau on the south. In the accompanying map this arbitrary line follows Yampa River. It might likewise have followed the crest of an anticline eastward from the Uinta Mountains, but since the line must in any case be arbitrary, the more definite location is preferred.

The Southern Rocky Mountains.—Between central Wyoming and northern New Mexico the southern Rocky Mountains form a continuous mountain area, interrupted only by such valleys as belong distinctively to a mountain country.

Except near the south end, the entire eastern boundary of this mountain province is easily traced on a contour map (Use U. S. Geol. Surv. 3-sheet map) and may be seen as a mountain front by an observer standing a few miles distant on the Great Plains. In southern Colorado and northern New Mexico, such observations are less satisfactory. This portion of the Great Plains province is itself very rugged, a high and deeply dissected plateau. Views of the mountain front must therefore be had from high points on the plateau.

The eastern boundary of the province is likewise clearly marked on the geologic map. In general the Cretaceous and all younger rocks belong to the Plains Province, the exceptions being only an extremely narrow belt of hogback foothills and an arbitrary detour to include the Spanish Peaks (volcanic) in the foothill belt. The very narrow zone of Jura-Trias, where present, belongs to the same foothill belt and therefore to the mountain province, which likewise includes all older rocks. The ranges thus fronting on the Great Plains are the Laramie, chiefly in Wyoming; the Colorado Front Range from near the Wyoming boundary to the Arkansas River; the Wet Mountains (*en echelon* with the Front Range) from the Arkansas to Huerfano Park; and the

Sangre de Christo Range (*en echelon* with the Wet Mountains) from Huerfano Park to the southern extremity of the province.

The southern limit of the Sangre de Christo range is definite both structurally and topographically. This granite-cored mountain uplift comes to an end at the Glorietta mesa. The boundary here is essentially at the Santa Fe Railroad. There are other mountains in line with the Rockies farther south but of different type, allied with those of the Great Basin and the Mexican Highland.

For sixty miles north of Santa Fe, the western boundary of the Southern Rocky Mountain province is not well defined. It becomes clear again in lat. 36° 40′ where the volcanic mass of the San Juan Mountains overlooks the Colorado plateau to the southwest. Here the boundary between mountains and plateau is essentially at the edge of the volcanic cover. A line may be drawn north from Santa Fe following the west foot of the Sangre de Christo Range near the Rio Grande and jogging to the west around the south end of the San Juan Mountains, leaving to the south in the plateau province, the broad flat plateau (Mesa de los Viejos) in which the Rio Chama has cut its canyon. Topographically this line is fairly clear and as a province boundary would be satisfactory. On the other hand the Jemez Mountains west of Santa Fe, though somewhat isolated, are very similar to the Rocky Mountains in history and topography. Their western member, the Nacimiento Mountains, resembles the Sangre de Christo, while the remaining (eastern) portion is lava-covered. It is a southern extension of that great area of volcanic rocks which comprises the San Juan Range of Colorado and northern New Mexico. There is much to be said for drawing the province boundaries in such a way as to include these mountains in the Rocky Mountain province. The narrower boundary of the mountain province is here used, but a better knowledge of the region might cause the alternative line to be adopted. In tentatively assigning the Jemez Mountains to the plateau province it may be remembered that there are also other similar isolated centers of orogenic uplift and volcanic activity in that province.

In southwestern Colorado the mountain province comprises, in the main, all rocks older than Mesozoic, together with contiguous areas of eruptives. A line so drawn will include in the mountain province south of latitude 39° 30′ the following contiguous ranges and groups: San Juan, Quartzite, La Plata, Bear River, San Miguel, Uncompagre, West Elk, and Elk. Certain parts of this line are highly irregular by reason of spurs and embayments in the mountain front. Moreover, the agreement of this front with the actual contact of the rocks mentioned is necessarily only approximate because of erosion and minor structural features such as hogback foothills. The two lines, topographic and geologic, are, however, fundamentally related. The final appeal is, of course, to the topographic line, the geologic line being understood to be interpretative rather than definitive. Further refinement in the drawing of this line awaits more detailed work.

North of latitude 39° 30′ the criterion here given fails to apply, because of the White River Plateau. This elevated tract just west of the 107th meridian is a true plateau, capped by nearly horizontal Paleozoic rocks and later eruptives. In a general way it is separated from the mountain province with its deformed strata by Grand River. This is arbitrary and approximate at best, for the contrasted types of structure and topography are much interlocked at this place. The length of line thus unsatisfactorily defined is, however, not more than fifty miles. Farther north the criterion used above is quite satisfactory, the Park Range consisting of pre-Mesozoic rocks with a narrow strip of Mesozoic foothills.

The southern Rocky Mountain province terminates at the north in three branches or prongs which indent the Central Rocky Mountain Basin. These are the Sierra Madre or Encampment Mountains (the northern extension of the Park Range), the Medicine Bow Range and the Laramie Range. The province boundary here has already been traced. Except for a local and narrow belt of Mesozoic foothills, all rocks of that age and younger are excluded from the mountain province.

THE COLORADO PLATEAU.—South of the forty-eighth parallel, the Rocky Mountain provinces are separated from the Sierra Nevada and Cascade Mountains by a strip of plateau whose greatest width is about 600 miles. This great region is divisible into three or more provinces according to the basis adopted. One of these, the Colorado Plateau (in a rough way the drainage basin of Colorado River as far down as the great canyon) has its center in southeastern Utah and northeastern Arizona. This province is characterized by elevated, horizontal, well indurated strata, locally covered by lava flows. As thus characterized the province is distinguished from its neighbors on all sides except the Central Rocky Mountain Basin. The mountains on the north and east are not composed of horizontal rocks. In the Great Basin on the west, the Arizona Highlands on the south and the Trans-Pecos Region on the southeast, horizontal beds are in general, or to a large extent, limited to the Quaternary filling of local basins. These beds are not indurated and not relatively elevated and are not in general subject at present to plateau dissection.

The features here named as characteristic of the Colorado Plateau fail to distinguish it from the Central Rocky Mountain Basin. The sixty-mile line which separates these provinces is avowedly arbitrary, the separation being made in the interests of compact form and in order to conform so far as practicable to the customary use of the name "Colorado Plateau."

The least satisfactory portion of the boundary is in New Mexico. That portion of the boundary which concerns the Jemez Mountains west of Santa Fe has already been discussed in speaking of the Southern Rocky Mountain province. South of these mountains the line separates the Colorado Plateau on the west from the Trans-Pecos Region on the east. The characteristic of this latter region is essentially that of the Great Basin to be discussed later. It is sufficient to say here that subaerial Quaternary deposits made in arid basins are characteristic of these provinces and are rare or unimportant on the Colorado Plateau. It is found simplest therefore, and on the whole consistent, to draw the province boundary southward from Santa Fe at the west side of the Quaternary floor of the Rio Grande Valley.

Leaving the Rio Grande Valley and turning southwestward in latitude about 34° 30′, the line becomes indefinite, partly for want of sharp distinctions in nature and partly, perhaps, because of the lack of detailed surveys of the region. As drawn on the accompanying map the line passes west of the Sierra Ladron and Magdalena Mountains; thence westward on the south side of the Gallina and Datil Mountains. These east-west ranges, while distinctly an orogenic uplift, should be classed with similar isolated uplifts in the Colorado Plateau rather than with the mountains of the Trans-Pecos Region which are characteristically tilted blocks with a north-south trend. With the lines so drawn, the plains of San Augustine are left to the south in the Trans-Pecos Province, being apparently similar to the many other isolated basins of that province and of the Great Basin. Along the west side of this basin the line trends directly southwestward to the Arizona boundary, following the straight line of San Francisco River and its headwaters the Tularosa, excluding from the plateau the Mogollon and Tularosa ranges.

At the Arizona state line, latitude about 33° 30′, the province boundary turns abruptly to the northwest. It crosses the Clifton Quadrangle (see U. S. Geol. Surv. Topographic Sheet), leaving all good plateau remnants to the north. Thence northwestward to Fort Apache (long. 110° W.), the line follows essentially the divide between the Gila River and the Little Colorado. On the north side of this divide the headwaters of the Little Colorado have incised themselves but little and the plateau is in large part preserved. On the other hand the tributaries of the Gila have steep gradients and among them the plateau is in large part destroyed. Continuing westward along the same divide, the line follows the edge of Mogollon Mesa, the southern border of the Colorado Plateau. Farther west the plateau edge is far from a straight line, being indented by some large valleys. The province line should follow the edge of the Black Mesa, the Yampa Cliffs and the Grand Wash (fault) Cliffs. The last named cliffs continue northward to Virgin River in southwestern Utah. North of that river the line follows Rush Lake Valley and Parowan Valley to Fremont's Pass (lat. 38°), and beyond that the valley of Sevier River, thus leaving on the east the "High Plateaus of Utah" composed of nearly horizontal rocks and on the west the Iron, Tushar and Pavant Mountains which belong to the Great Basin type.

Within the great area thus surrounded are many plateaus needing individual description, separated by fault scarps, erosion scarps and deep canyons. They differ in elevation, climate and degree of dissection. There are also volcanic mountains and local orogenic uplifts interrupting the general plateau character; but as a major physical division of the United States it has, amid great variety, certain fairly constant characteristics which consistently distinguish this province from its neighbors.

THE DESERT PLATEAUS.—West and south of the Colorado Plateau is a vast area marked by certain dominant characteristics from central Oregon to the interior of Mexico. This great region is, for the most part a highland, but even where low, as in southeastern California and southwestern Arizona, the most characteristic features are the same in kind though differing in their development.

No single name is in use to designate this entire region. Its northern half is called the Great Basin. Its southern half is the northward continuation of the Mexican Highland. That portion of this highland comprised within the United States is designated under the names of at least three subdivisions, the Colorado Desert, the Arizona Highland and the Trans-Pecos Region. Because of the continuity of essential features throughout the entire region it is, for some purposes, desirable to regard this large region as a single province and to designate it by a single name, the more so because its subdivisions can not be sharply delimited. For lack of a better, the name Desert Plateaus is here used for the whole region.*

The distinctive features of these Desert Plateaus are isolated, nearly parallel mountain ranges (presumably fault blocks) and intervening plains made in the main by deposits of waste from the mountains. These latter deposits are in their original horizontal or nearly horizontal position. They are locally very deep and generally unconsolidated. The consolidated older strata and lavas which make the mountains are only locally horizontal. In general, they are deformed, and locally very much so.

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* A stricter use of the term "Mexican Highlands" would not include the Colorado Desert. The latter is rather a northern extension of the Sonoran province of Mexico, which is not, on the whole, an elevated region. The Colorado Desert has so much in common with the other subdivisions here named that it seems desirable to include all under a comprehensive name, but it is not certain that "Desert Plateaus" is the best name that could be chosen.

With respect to the above mentioned structural features, this great region is clearly contrasted with the Colorado Plateau. It is less sharply contrasted with the mountains on its border, notably the Wasatch and Sierra Nevada. The greater size of these two ranges makes them exceptional and their contiguity with other ranges justifies the making of certain *mountain provinces.* The Basin ranges on the other hand are smaller and isolated. Aside from these things there is no essential difference between the mountains within the Great Basin and those on its border.

The Great Basin.—The northern half of the great region here mentioned has been known as the Great Basin since the expedition of John C. Fremont. The drawing of its boundary depends on which one of its characteristics is regarded as most significant and is therefore chosen as the criterion by which to determine its limits. The presence of block mountains and intervening waste plains has already been mentioned. Another fact which is true of nearly the same area is that the drainage fails to reach the sea and evaporates from sinks and salt lakes. The name Great Basin is frequently used as synonymous with the " area of internal drainage " in western United States. This fact appears at first to be significant as a feature and definite as a criterion for drawing boundaries, but an attempt to draw a line by this criterion soon shows that there is a broad borderland to which this criterion is inapplicable. It would, in the first place, require that the western boundary of the Great Basin be drawn at the crest of the Sierras instead of at the foot, whereas it is evident that the eastern slope of that range is just as much a part of the mountain province as the western slope. The physiographic history, features and classification of the eastern slope of the Sierras is in no way dependent upon what becomes of the water twenty miles farther east. In a similar way some stream valleys leading outward from the Great Basin may contain through-flowing streams or may, in wet seasons, deliver water to permanent streams in other provinces. Thus the through-flowing Pitt River, a branch of the Sacramento, rises in northeastern California where it and its tributaries (many intermittent) drain a large area which is universally regarded as a part of the Great Basin. Other streams of the same character flow through the same kind of country in other directions and do not reach the sea. So far as physiographic character and classification are concerned, the upper basins of such streams cannot be grouped according to the destination of their waters. It is doubtful whether divides and stream courses ever make significant physiographic boundaries except where the location of the divide or stream is merely incidental to some more significant fact, generally one of structure.

The most central and significant feature of the Great Basin seems to be the accumulated waste from its higher parts, building plains in its lower parts. This is related on the one hand to the structure of the province and on the other to its climate. Along streams entering the Great Basin from other provinces, such deposits do not begin until the proper limits of this province are reached. Again, where such deposits are found along stream courses leading outward from this province to through-flowing streams, their presence indicates ineffective drainage in that portion of the stream basin where they are found. This inability of the running waters to forward the waste from higher slopes is a much more important fact in the *character* of the country than the mere fact that the water is, at some remote point, evaporated or that it ultimately reaches the sea. In addition to the above-mentioned considerations, these surficial deposits are very important in the classification of soils, and it is desirable so far as possible that the conventional boundaries of physiographic provinces should take soils into consideration. On the whole it seems best to include within the Great Basin proper, all that area between the Rocky Mountains and Colorado Plateau on the east and the Sierra Nevada and Cascade Mountains on the west which is characterized *primarily* by the accumulation of detritus (chiefly subaerial) in basins, *secondarily* by block faulting which occasioned most of the basins, and *incidentally* by internal drainage.

The eastern boundary of the Great Basin, against the Rocky Mountains and the Colorado Plateau, has already been traced. The criteria by which these provinces were defined and limited are consistent with that here proposed for delimiting the Great Basin. Immediately to the west of the lines already drawn, Quaternary sediments begin to form the floors of basins between elevations which are for the most part (presumably) block mountains.

On the north, the Great Basin must be delimited from the Snake and Columbia River Plateaus. The boundary here is confessedly vague whatever criterion be used in drawing it. In southeastern Idaho the line runs parallel to Snake River on its south side. If it be drawn in such a way as to leave all the Basin Ranges to the south, running tangent to their northern ends, it will at the same time follow essentially the northern edge of the Quarternary basin deposits. This is not the limit of the Snake River drainage basin which extends far to the south between the several mountain ranges. North of the line here proposed is the basaltic surface which is characteristic of the Snake River Plateau. Passing southwestward into Nevada, the line as defined above becomes essentially the divide which limits the Snake River basin. Northwestward from this point the characteristic topography and sediments of the Great Basin can not be better delimited than by following the Snake River divide. This assigns to the Great Basin the flat central basin of Oregon with its sandy desert, lost rivers and salt lakes. North of latitude 44° the line enters the Columbia drainage basin and goes west on the north side of Crooked River to its junction with the Deschutes. This is done in order to include in the Great Basin the entire area of Quaternary sediments, the larger part of which drains into the salt lakes of central Oregon but the northern end of which is in the basin of Crooked River. That the drainage of this stream should reach the Deschutes and thereby the ocean, while streams through similar country in the opposite direction reach salt lakes, is not considered a sufficient reason for assigning the northern end of this otherwise uniform area to a different physiographic province.

By extending the line west a few miles to the foot of the Cascade Mountains, a part of the basin of Deschutes River is assigned to the Great Basin province. This is satisfactory enough for thirty or forty miles above (south of) the mouth of Crooked River, but not so satisfactory farther south where the altitude is higher, the rainfall greater and the stream valley is shut in by mountains on the east as well as on the west. It may be that these mountains on the east (the Walker Range) can be treated as a spur of the Cascades, or at least as belonging to the same province, thus throwing the upper Deschutes valley into the mountain province with which its character is quite consistent. The line is tentatively so drawn on the accompanying map.

From latitude 43° southward to Lake Tahoe (lat. 39°) on the California-Nevada boundary, the province boundary is copied from Diller.[30] To a point a little south of the Oregon-California boundary it follows essentially the western edge of the Quaternary sediments, much generalized. The topographic break between basin floors on the east and mountains on the west is nowhere very far from this contact. Farther south in California, the eastern front of the mountains is fairly definite though not indicated on the geologic map by any contrast in rocks.

At intervals for a considerable distance north of Lake Tahoe the eastern front of the Sierra Nevada is determined by faults. From Lake Tahoe southward to the end of the range this fact is very striking. In the generalized mapping of large areas no better province boundary can be adopted than this great fault line. The line on the accompanying map follows this fault as shown on Map 1 in the atlas of the California Earthquake Commission, 1906. It is, of course, generalized and may represent as a single fault what is really several or many faults *en echelon*. Presumably the actual fault has not been traced throughout the whole distance but inferred locally from the topography. In any case, it is a good generalization of the mountain front and the province boundary.

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[30] U. S. Geol. Surv. 14th Ann. Rep., Pt. 2, Pl. XL.

In common usage the application of the name Great Basin in southern California is very indefinite. Powell in his sketch of physiographic provinces (1896) limited it only by the Pacific Ocean and Colorado River, allowing it an indefinite extension into Lower California. Elsewhere the name is limited to the area whose drainage does not reach the sea. This fact has been shown to be incapable of detailed application for purposes of classifying land areas. A much more significant fact in physiographic description is this: North of latitude 35° 30′ the space occupied by the block mountains is more than half the total area; south of that line it is not more than one-sixth of the total.[31] North of that line the mountains are not only longer and broader but higher and composed of younger rocks. The mountains are less advanced in the erosion cycle and the intervening basins are less completely filled with the waste of the mountains. These contrasted types of country are fairly well separated by an arbitrary east-west line in lat. 35° 30′. The area north of that line is well known popularly and scientifically as the Great Basin; that to the south may best be included under the name Colorado Desert.

The Colorado Desert.—The above name has been in general use to designate a region of indefinite extent on both sides of the lower Colorado. The region thus designated extends without significant change of character to the Coast Ranges on the west and the Arizona Highlands on the east. As the whole is homogeneous in its essential features and the " Colorado Desert " has never had definite boundaries, no violence will be done in extending it to its natural limits. The term Lower Colorado Basin (used by Bowman) may be used if preferred, though a large part of it belongs to the area of internal drainage and a considerable portion drains to the sea by other streams.

This sub-province may be differentiated from its neighbors as an area of old and relatively small block mountains separated by broad plains which represent for the most part (not exclusively) waste-filled basins. It is bounded on the west by the Sierra Nevada (line described above) and, south of that, by the Coast Ranges. The line which separates this mountain province from the desert is essentially that which separates the older intrusive rocks from the Quaternary sediments. With the latter are included the patches of pre-Cambrian which make the old block mountains. The line on the accompanying map is drawn by this criterion but guided in detail by the great fault lines shown on the map of the California Earthquake Commission.

The boundary of the Colorado Desert against the Arizona Highland cannot be given exactly. It is a line between sub-provinces only and as such does not express a very sharp contrast.

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[31] Compare the geological map of North America, U. S. Geol. Surv. 1911; also Bowman, Isaiah—Forest Physiography, Pl. IV and pp. 222.

The Arizona and Trans-Pecos Highlands.—The Arizona Highland is in the main a southeastward extension of the Great Basin (though drained to the sea). In smaller part it is the eroded margin of the Colorado Plateau stripped of its overlying beds. In the size of its block mountains and in the proportion of mountain to plain, this region resembles the Great Basin rather than the Colorado Desert. In passing from this province southwest, the size and proportion of mountains decreases, hence there is gradation rather than a sharp line. However, despite this gradation, the contrast is quite enough to determine very different types of landscape which are well recognized and geographically important.

The Trans-Pecos Highland differs in no essential way from the Arizona Highland. It has some broader plains and the trend of its block mountains is north instead of northwest, as in Arizona. The essential description of both are contained in that of the Great Basin. The division between the two is an arbitrary north-south line in western New Mexico.

THE COLUMBIA PLATEAU.—Included between the Northern Rocky Mountains, the Cascade Range and the Great Basin, is the Columbia Plateau, so named because it lies within the drainage basin of Columbia River. As a plateau of horizontal rocks (with only local exceptions and these not on the border) it is necessarily contrasted with the adjacent mountains. On the south, however, it is bordered by another plateau, the Great Basin. The distinguishing characteristics of the Great Basin have already been given. That of the Columbia Plateau is a surface built up by lava flows. On this are local patches of sediments (Tertiary) but not of the Quaternary, and recent detritus indicating inefficient drainage so highly characteristic of the Great Basin. Such statements as this last are necessarily of general application and should not be pressed too far. The distribution of such deposits must be taken from geologic maps, in this case chiefly from the map of North America (U. S. Geol. Survey, 1911). Surficial deposits commonly appear on geologic maps only where they are so thick as to obscure the nature of the underlying hard rocks. Much thinner deposits not shown on maps may be important in determining the nature of the soil and thereby the geographic character of the region. Hence it is not to be concluded that the Columbia Plateau has no surficial Quaternary deposits of geographic importance. It is also to be noted that there are some horizontal lava surfaces in the Great Basin presumably not covered with detritus. Nevertheless, despite these details, there is no other criterion which affords so good a generalized boundary and so *significant* a distinction between the Great Basin and the Columbia Plateau. With the essential characteristics once agreed upon, by which these provinces are defined, the line which separates them will be more and more critically located as detailed field study proceeds.

The line separating the Columbia Plateau from the Cascade Mountain province must be inferred from topographic maps. Both structurally and topographically the eastern border of the Cascades in Washington is irregular and the line here given is at best an approximation. In Oregon the mountain front follows a more regular line along the west side of the Deschutes Valley.

THE CASCADE MOUNTAINS AND SIERRA NEVADA.—West of the great belt of plateaus described above, lie the mountain ranges which stretch along the Pacific Coast. They are in part contiguous, but separable into units of distinct character. It would be very desirable to assign to each one of these units one of the familiar names now in use and make the application of each name coextensive with a certain character of mountains. This can be done only in part. To some extent the characters of the several ranges grade and merge and some are not uniform in character throughout their extent.

The Sierra Nevada may *almost* be described as a fault block composed of old and much deformed sedimentaries and intrusives, baseleveled and then uplifted with a westward tilt. As thus defined, the range terminates in latitude 40° as shown by Diller.[32] In common usage the name Sierra Nevada is extended farther north, sometimes to the Oregon state line. This usage ignores the only important natural line of distinction.

The eastern boundary of the Sierra Nevada province has already been traced. The great fault which limits the mountains on the east curves to the west at the southern end of the range and determines its limit in that direction. On the west side the mountain province is essentially coextensive with the rocks older than Quaternary. This allots the local Tertiaries of the foothill belt to the mountain province. The topography of this zone grades into that of mountains but is in clear contrast with that of the Quaternary plain on the west.

The Sierra Nevada are continuous at the north with the Cascade Range. The latter is a broadly uplifted belt either composed chiefly of, or veneered with, volcanic rocks as far north as latitude 47° 30′. Farther north the volcanic cover is wanting. Therefore, whatever unity there is in the entire Cascade range is not to be found in its rocks. It appears however, that the features characteristic of the entire range are due to physiographic history more recent than some of the lava flows. This history includes approximate peneplanation and later uplift and dissection by water and ice. It is thus seen that the Cascade Range is not very clearly separated from the Sierras. Their histories are in part similar. Although a contrast of rocks is taken to differentiate the two ranges in latitude 40°, a similar contrast occurs within the Cascades themselves in latitude 47° 30′.

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[32] U. S. Geol. Surv., 14th Ann. Rep., Pt. 2, Pl. XL.

Beginning at the south end of the Cascade Range, its western boundary is a northward continuation of that of the Sierra Nevada, namely, the edge of the Quaternary deposits. North of the Quaternary-filled Great Valley of California the Cascade Range is contiguous on the west with the Klamath, or separated only by the narrow valley followed by the Southern Pacific railroad. The western edge of the Cascades as drawn by Diller is the edge of the volcanic flows. From central Oregon north, the mountains slope to the Willamette valley which, with its floor of Quaternary sediments, is analogous to the Great Valley of California. The province boundary here is the edge of the Quaternary deposits or, perhaps better in this case, the edge of the volcanic flows. No geologic contact can be followed consistently. It is necessary to follow the mountain foot by the best topographic data available and await future more detailed studies. North of the Columbia, the Puget Sound Basin is again topographically analogous to the Valley of California, the province boundary following the eastern edge of the Quaternary deposits to the Canadian line, leaving the older Tertiaries in the mountain province.

The Coast Ranges.—The mountains which border the coast from the Straits of Juan de Fuca (Canadian boundary) on the north to Mexico, are neither a single range nor alike in character and history, but they are for the most part contiguous and may be treated as a single general province. The local lowlands which intervene between the mountains and the coast are so narrow as to justify their inclusion in the mountain province, though some of them, particularly in southern California, deserve prominent mention.

The Olympic Mountains of Washington are an entirely isolated group. On the east they approach so close to Puget Sound that the shoreline may be considered the province boundary. South of the mountains the continuity of the chain is broken by an east-west strip of lowland 25 or 30 miles wide, connecting the narrow coastal plain on the west with the Puget Sound Basin on the east. The latter needs independent treatment as a geographic unit. Neither its name nor its geographic description can be given such broad application as to cover the coastal plain. Convenience requires that it be limited somewhere on the west by an arbitrary boundary where this transverse lowland occurs. The lowland thus excluded from the Puget Sound Valley may be treated as a local feature within the Coast Range Province. Such arbitrary lines have little use in physical descriptions but since the term Puget Sound Basin or "Sound Valley" or Sound-Willamette Valley is bound to be in general use as designating a geographic unit, it must be assigned some definite limit if statistical statements are to be consistent.

South of this transverse lowland is a range of hills or low mountains with only local elevations above 2,000 feet. It is commonly spoken of as a southern extension of the Olympic Mountains. Geologically it is poorly distinguished from the valley on the east. It descends to a level of about 500 feet and for want of better data the province line may be drawn along that contour. On the accompanying map this line has been continued almost directly northward as the arbitrary western boundary of the Sound Valley.

South of Columbia River, the foot of the mountains must again be taken from the best topographic data available, generally at about the 500 or 1,000 foot contour. Beyond the southern limit of the Willamette Valley the Coast Range province touches the Cascades on the east, the latter being here coextensive with the recent volcanic rocks.

The Klamath Mountains in southern Oregon and northern California are essentially, as outlined by Diller, that part of the Coast Range province whose substructure is of Paleozoic rocks and older intrusives. Answering to this geologic contrast with its neighbors, are certain physiographic characteristics which justify treatment as a sub-province. On the east it touches the Cascades along the line already indicated.

Throughout the entire length of the Great Valley of California the eastern foot of the Coast Ranges is definitely marked where the Quaternary deposits begin. South of this valley and of the Sierras, the limit of the Coast Range province has already been traced as the western limit of the Colorado Desert.

The most important lowlands included in this province stretch from Los Angeles to San Bernardino in latitude 34°. They are outlined on the accompanying map. The nature of the boundary is very similar to that of the Central Valley of California.

Pacific Coast Valleys.—The Sound-Willamette Valley, or, for short, the Sound Valley, is a structural and topographic trough with an area of seven or eight thousand square miles stretching south from Puget Sound between the Cascades and the Coast Ranges. It is a very important feature both geologically and geographically and analogous to the great central Valley of California. Its boundary against the Cascades has already been traced empirically. It does not agree throughout with any evident geologic line by which it can be interpreted. The western boundary is in large part independent of geologic contrasts so far as can be seen from available maps. For the present the valley province must be delimited by generalized contour lines.

The limits of the similar Valley of California have already been traced in speaking of the neighboring provinces. Its floor is practically coextensive with the area of Quaternary deposits shown on the geological maps.

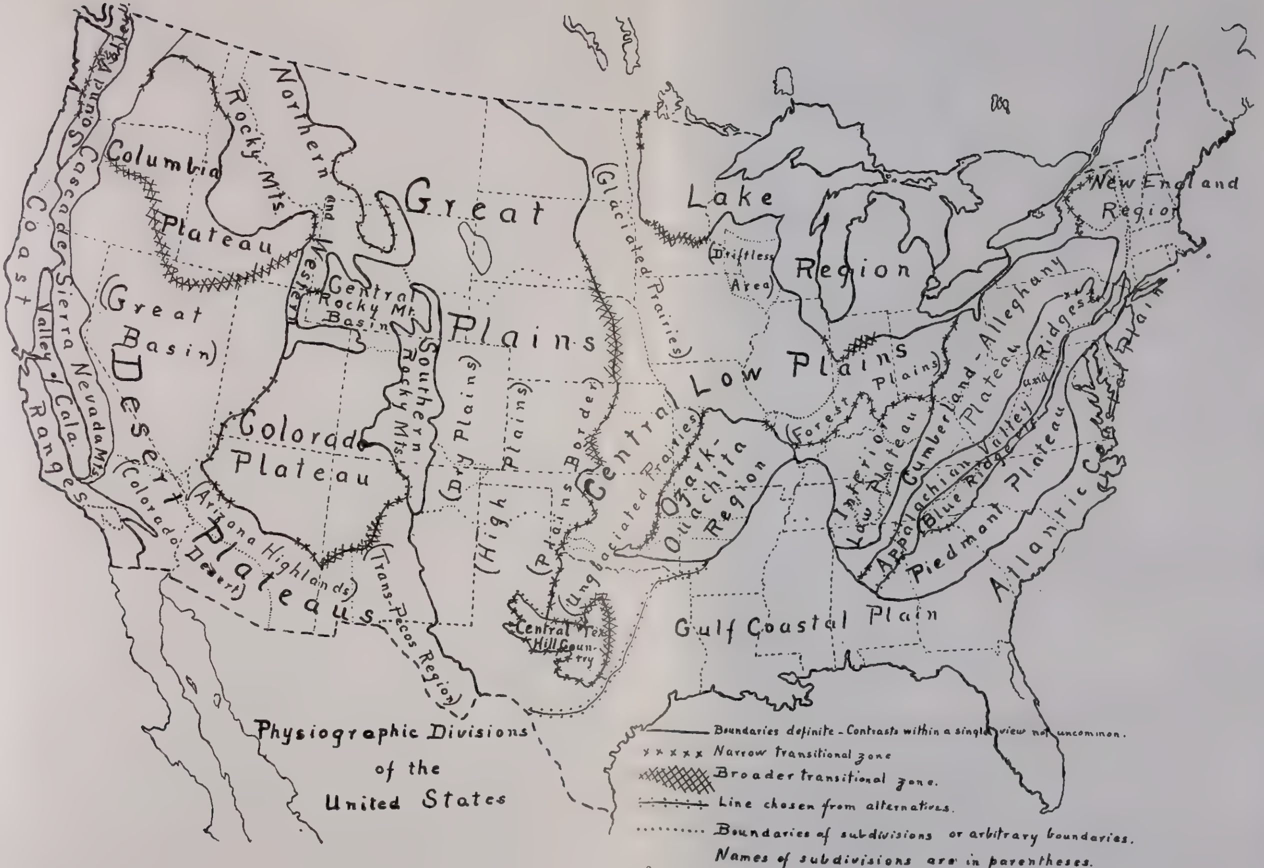
Physiographic Divisions of the United States
Boundaries definite - Contrasts within a single view not uncommon.
x x x x x Narrow transitional zone
Broader transitional zone.
Line chosen from alternatives.
Boundaries of subdivisions or arbitrary boundaries.
Names of subdivisions are in parentheses.
Coast Ranges
Puget Sound Valley
Cascade Sierra Nevada Mts
Valley of Cala.
Columbia Plateau
Northern Rocky Mts.
Northern and Western
Central Rocky Mt. Basin
Southern Rocky Mts.
(Great Basin)
Desert Plateaus
(Colorado Desert)
(Arizona Highlands)
Colorado Plateau
(Trans-Pecos Region)
Great Plains
(Dry Plains)
(High Plains)
(Plains Border)
Central Texas Hill Country
Lake Region
(Driftless Area)
(Glaciated Prairies)
Central Low Plains
(Unglaciated Prairies)
(Forest Plains)
Ozark-Ouachita Region
Interior Low Plateau
Cumberland-Allegheny Plateau
Appalachian Valley and Ridges
Blue Ridge
Piedmont Plateau
Atlantic Coastal Plain
Gulf Coastal Plain
New England Region

FIG. 2.

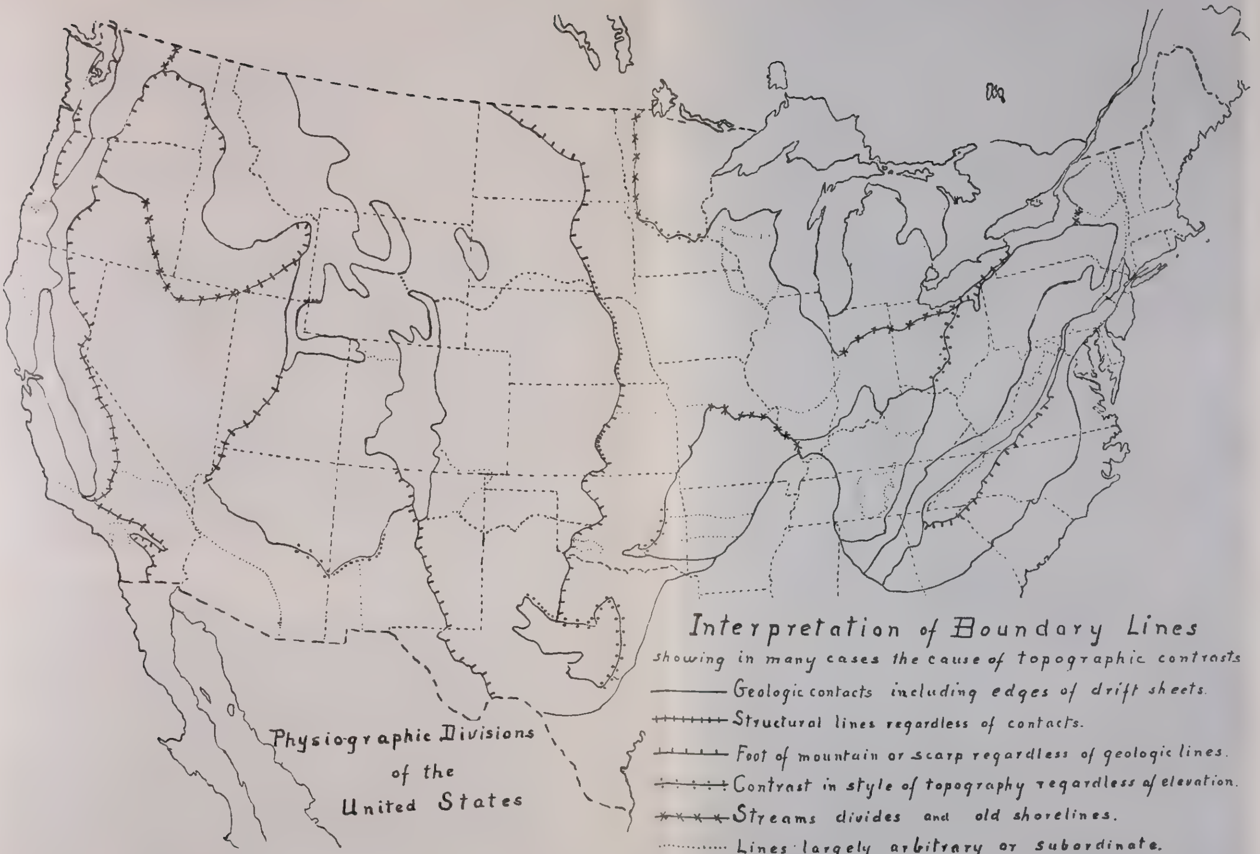
Physiographic Divisions
of the
United States
Interpretation of Boundary Lines
showing in many cases the cause of topographic contrasts
Geologic contacts including edges of drift sheets.
Structural lines regardless of contacts.
Foot of mountain or scarp regardless of geologic lines.
Contrast in style of topography regardless of elevation.
Streams divides and old shorelines.
Lines largely arbitrary or subordinate.

Fig. 3.

TITLES AND ABSTRACTS OF PAPERS

PRINCETON, 1913

Presidential Address—Henry G. Bryant.
Government Agencies and Geography in the United States.

R. H. Whitbeck.
A Geographical Study of Nova Scotia.

Lying nearer Europe than does New England, having a similar soil and climate and settled as early, possessing many excellent harbors, endowed with productive fisheries and rich coal deposits, and able to get the iron of Newfoundland easily, peopled by immigrants from the best European stocks, the province of Nova Scotia has now, after 300 years, fewer people than the city of Boston. Its total manufacturing output is less than that of single companies in New England, and the province has shared but slightly in Canada's economic growth. It is largely due to a single geographical fact—isolation. Nova Scotians present an example of a vigorous and ambitious people—denied by their geographical limitations adequate employment in business or industrial lines—turning their efforts into intellectual channels and then finding it necessary to seek promotion beyond the bounds of their home province. The chief product of the province has been *men*. Changes now in progress indicate an industrial awakening, and an industrial future.

W. M. Davis.
The Mission Range, Montana.

The Mission range in northwestern Montana seems, when seen from the west, to be a meridional fault block, for the most part maturely dissected by simple valleys between normal spurs. The general skyline suggests that the deformed strata of which the range is composed were reduced to small relief in a former cycle of erosion; while the gradual increase of crestline altitude from its low beginning in the north to its high ending in the south, through a length of 70 miles between an open valley on the east and a broad lowland on the west, indicates an initial inequality of uplift. The higher summits near the southern end of the range are sharpened chiefly by the southward growth of mature cirques in the neighboring valley heads, below which well defined troughs descend between normally dissected spurs to the mountain base, whence moraines extend half a mile forward on the piedmont plain. Two small glaciers lie in the highest cirques. The strength of the glacial forms decreases northward with the diminution in the height of the range, until in the 22nd or 23rd valley-head they are small and faint. All the lower northern end of the range for some fifteen miles shows strong scouring by the overriding portion of a long and broad Canadian glacier—the Kootenay-Flathead glacier—whereby uneven and irregularly rounded knobs and ledges are developed with significant loss of height. Thence southward to the middle of the range, the spurs and valleys of the western slope are all strongly truncated, but to a progressively decreasing altitude, by the terminal part of the same great Canadian glacier, so that the range there has normal forms aloft and glaciated forms below. The normal forms consist of rounded domes between maturely open valley heads, the more southern ones of which are increasingly troughed, as above stated; the glaciated forms below consist of bared, rounded and rugged ledges, all uniting in a nearly continuous, battered wall, little interrupted by salients or reentrants; and the two parts are separated by a line that slants gradually to the south and is neatly marked by a series of morainic embankments across each truncated valley end, so that the normal forms increase in dimensions above it, and the glaciated forms decrease in dimensions below it, southward to where a continuous embankment, gradually departing from the flanks of the range, turns westward across the adjoining lowland as a well defined morainic range, a mile broad, 500 or 600 feet high, with many hills and hollows, separating Flathead lake on the north from Flathead plain on the south.

William Libbey.

The Distribution of Earthquakes.—Read by Title.

A Subject Catalogue of Geographical Periodicals.

J. Russell Smith

The Tree as a Factor in Man's Adjustment to the Arid Environment.

In the search for water, the roots of some trees penetrate to great depths or have long lateral development. Some trees also have great ability to seize and hold water. The tree has permanence, and therefore is ready to avail itself of water opportunities when they arise. These factors give the tree a superiority over the short-lived grains in the struggle for subsistence in a region of scanty rainfall. Proof of this is to be found in the crop failures and breaking land booms of many sections of the American Great Plains, where the average rainfall is from 12 to 18 inches. These failures are based on a grain agriculture while the tree agricultures of Ifax in Central Tunis and of Matinata on the edge of the Sahara are prosperous on a rainfall of ten inches or less.

Robert DeC. Ward.

The Weather Element in American Climates.—Presented in full herewith.

Howard Palmer (Introduced by W. L. G. Joerg).

Glacial Features of the Selkirks.

Glacial systems of the Selkirks, with special reference to the Sir Sandford Glacier, the largest in the range.

Richard E. Dodge.

The Geography of Power in Manufacturing in the United States. —Read by Title.

A study of present distribution of steam, gas, water and electric power used in manufacturing in the United States, with a consideration of the rise and fall of these types in the last fifty years as related to other geographic conditions.

Oliver L. Fassig.

The Frostless Period in Maryland and Delaware.

A discussion of the frostless period in Maryland and Delaware based upon a record of the occurrence of the last killing frost in Spring and the first killing frost in Fall, covering a period of about 25 years in the states named and at fifty stations having weather records varying from five years to forty years. Incidentally the paper discussed the relative merits of methods employed in determining the length of the frostless period.

Roy C. Andrews (Introduced by Ellsworth Huntington).

Exploration in Northern Korea.

Until 1912, portions of the dense forests lying between the Tumen and Yalu rivers in southern Manchuria and northeastern Korea had remained unvisited by white men. To make a zoölogical exploration of this region, the American Museum of Natural History sent an expedition in 1912. Entering from the east coast, the party travelled through the dense forested wilderness to the base of the " Long White Mountain," crossed the watershed separating the Tumen valley from that drained by the Yalu river and its tributaries, and finally reaching the Yalu continued down it by boat to the west coast of the peninsula.

Leon Dominian (Introduced by Cyrus C. Adams).

Geographical Influences in the Delimitation of Spheres of Foreign Interests in Asia Minor.

Lawrence Martin.

Glaciers and International Boundaries.

The oscillation of ice fronts adjacent to the Alaska-Canada boundary has introduced a new principle into international law. This is that, when a boundary is to be located a stated distance from the ocean, the coast at the head of a bay, fiord, or inlet shall not be determined by the chance position of the frontal sea cliff of a tidal glacier at the time of adjudication and surveying of the boundary.

The boundary between Alaska and Canada was to be located 10 marine leagues or about 35 miles from the Pacific Ocean. The joint boundary commission determined that the boundary should not be merely 35 miles from the ocean but should lie inland from the heads of all the fiords, the spirit of the treaty denying Canada any harbors on this coast. The boundary surveyors, however, have regarded the fronts of tidal glaciers as the heads of fiords and have located the boundary accordingly. The 12 mile recession of Grand Pacific Glacier between 1894 and 1912, permitted the fiord waters to extend across the international boundary in Glacier Bay, giving Canada a harbor. This was observed by N. J. Ogilvie of the Canadian Boundary Survey, who mapped a 7,425 foot recession of Grand Pacific Glacier between June 1 and August 1, 1912.

The 60 mile recession of Grand Pacific Glacier from 1794 to 1912 may be repeated elsewhere, for example (a) at the Seward tributary of Malaspina Glacier, or (b) at Hubbard Glacier, or (c) at Nunatak Glacier in Yakutat Bay, or (d) at Muir Glacier, or (e) at Taku Glacier south of Juneau. In these five places tidal ice fronts are now only about 25 miles from the same international boundary, and exhumed forests indicate an earlier glacier minimum which was not necessarily over a century and a half or two centuries ago. Indeed Mt. St. Elias which was 35 miles from the coast when the boundary was fixed in 1894 has been (a) only about 15 miles from the Pacific in the old Icy Bay of the eighteenth century (1794 etc.), and (b) in 1913 is only 26 miles from the ocean at the head of the new Icy Bay formed since 1909 by the nine mile recession of Malaspina Glacier.

The new Canadian port in Glacier Bay, gained in 1912, was lost in 1913, when a National Geographic Society expedition discovered a 4,000 foot advance of the same glacier and the destruction of this harbor. However, it is by no means certain that Yukon Territory may not, within the lifetime of ourselves, have a more permanent port east of Mt. St. Elias, or British Columbia a roadstead in the region southeast of Juneau.

F. E. Matthes.

Lessons in Glacial Erosion from the Yosemite Region.

Austin H. Clark.

The Atlantic Ocean as an Inland Sea.—Read by Title.

It has been pointed out by several geologists that the Atlantic Ocean, instead of being a true ocean, is in reality an inland sea, partaking more of the character of the Mediterranean. Recently, Professor Woekow has shown that meteorologically also the Atlantic is an inland sea.

This question has never received attention from the biological side.

Considering for the present only the recent crinoids we find that of the 31 genera known from the Atlantic all but three occur in, or are represented by very closely allied genera in, the Indo-Pacific region, while these three exceptions occur as fossils in Europe; on the other hand in the Indo-Pacific region there are 50 genera not represented in the Atlantic; 8 families and one subfamily of another out of a total of 19 in the Indo-Pacific region are not represented in the Atlantic.

Therefore, as the Atlantic fauna is composed of 37½% of the (more generalized) elements of the Indo-Pacific fauna, without a single distinctive endemic type, it would appear that the Atlantic is biologically an inland sea of the Indo-Pacific.

Ellsworth Huntington.

The Anthropography of Guatemala.—Read by Title.

Guatemala is especially notable for two chief contrasts. One of these is the contrast between the dense lowland forests and the open highlands at elevations from five to eight thousand feet. In the lowlands communication is extremely difficult; the population is very scanty, and the people are in the lowest stages of civilization. In the highlands movement is comparatively easy; the population is so dense that almost every foot of land is cultivated; and all the civilization and power of the country are concentrated. The other contrast is that between the past and the present. Near the beginning of the Christian era the conditions seem to have been the reverse of those prevailing to-day, for the lowlands were the center of the highest civilization which has ever developed in America, while the highlands were comparatively backward.

Robert M. Brown.

The Effects of Levees on the Height of River Beds.

The paper discussed the widely accepted belief that the levees tend to elevate the river bed. Since the Po is generally cited as an example of this tendency, a history of the Po regulation and its results was summarized and the cases of the Nile, the Rhine and the Mississippi rivers considered. The natural tendency of a river to build up on its flood plain, the up-building of alluvial fans and deltas and the effects of general subsidence or uplift are elements of the problem which must be eliminated. A summary of the points of the paper follows.

The observation of the low water gages of rivers proves quite conclusively that there is no persistent upbuilding of the bed due to levees.

On streams or portions of streams where from the nature of the conditions aggrading is in operation, the upbuilding of the river bed after levees have been constructed will probably continue.

Deltas increase in area more rapidly in a leveed river and the increase in the length of the stream diminishes the slope and results in a slight deposit on the river bed. The amount is so small as to be imperceptible during a score of years.

The increase in the height of levees can be accounted for by the success of the engineers in confining an increasing percentage of the flood waters.

The elimination by stable banks and clothed slopes of some of the sediment from a stream flowing through its flood plain will minimize the amount of the temporary deposits in beds of rivers and furnish additional power by which the channel may be cleared of bars.

N. M. Fenneman.

Definition and Boundaries of Physiographic Provinces in the United States.—Printed in full herewith.

Isaiah Bowman.

The First Decade.

A series of maps was exhibited showing the distribution of the members of the Association of American Geographers, the center of "population," the center of gravity for the papers read, the center for published papers, and for annual meetings. In connection with these maps there was a discussion of the character of the papers. The publication, at the end of each succeeding decade, of similar maps and analyses of papers, in either the Annals or geographical journals might create wider interest in the Association's activities.

Results of Expedition to the Central Andes.—Read by Title.

Under the auspices of the American Geographical Society, a South American expedition was organized in March, 1913, for the purpose of completing certain problems begun in 1907. The fields of work were northwestern Argentina, the Copiapò region in Chile, and the Desaguardero Valley in Bolivia. The chief subjects of study were artificial terraces, the pastoral nomads of the lofty *Puna de Atacama*, the cattle trade across the Cordillera, the influence of droughts upon the population at the southern end of the *Desert of Atacama*, the succession of lakes in the interior basins on the high plateau of western Bolivia, and the testing of various physiographic explanations applied in 1907 and 1911 to regions farther north.

Eugene Wesley Shaw.

New Land and Water Areas Near the Mouths of the Mississippi. —Read by Title.

With this paper was presented a new reconnaissance map of about 800 square miles lying, for the most part, below the Head of the Passes, and a brief discussion of the mode of growth of the Mississippi delta. The present land border differs widely from that indicated on the latest coast chart and shows not a regular building out resulting from processes long active and operating in approximate equilibrium, but an extremely irregular growth, the coast having advanced in some places 6 or 8 miles and elsewhere not at all. Even more impressive is the fact that locally the coast line has retreated and that extensive new bays, lakes and bayous have developed. Among the processes which have been involved are the following in the approximate order of their importance: (1) The formation of crevasses leading to rapid building out in such places as The Jump, Cubit Gap, and Garden Island Bay. (2) Subsidence affecting the whole delta but some parts, particularly along the coast, more than others. (3) the so-called mud lump upheavals; (4) wave cutting and filling, and, (5) the improvement of the passes for purposes of navigation.

Mark Jefferson.

The Growth of American Cities.

To state that people are leaving the country more and more, is to put a misleading emphasis on a normal fact in the modern growth of population. The United States has 5 million more country people in 1910 than in 1900. People are leaving some country places and going to others. Rural population here grows almost as fast as total population in Germany. Really cities are springing up wonderfully in the United States as a result of country growth. It is normal that country population should be thinner than city population; that cities should take up a part of the natural increase of the country population, and this is what is happening.

W. M. Davis.

The Principles of Regional Exposition.

All geographical facts are described in terms of their mental counterparts. The mental counterparts are geographical concepts, which with their names may be called the mental equipment or outfit of a geographer. The recognition of external facts is greatly facilitated by the previous possession of their counterparts; hence a geographer's mental outfit ought to contain many and varied concepts. The record of observed facts is greatly facilitated by previous acquaintance with the names of their counterparts; hence the mental concepts should have a well developed terminology. There are to-day two unlike sets of mental concepts in use. One, the empirical set, is based on the averaged values of observed features, without regard to their origin. The other, the explanatory set, is formed by deducing ideal examples from the general explanations that have been found for particular cases.

If we now limit our problem to the description of land forms we find that the description of a region should begin with a general statement of its larger features, the smaller features should then be added in their relation to the larger features. A small-scale outline map showing the location of the described region, a map of larger scale showing its chief subdivisions and all local names used in the text, and one or several diagrams illustrating relations of structure to form, are so desirable as to be well-nigh indispensable. They may well be supplemented but cannot be replaced by sketches and photographs of the more important landscape elements.

Explanatory concepts are in most cases greatly to be preferred for the description of land forms, because they are more varied and more definite than empirical concepts. Those who use explanatory concepts for forms, the origin of which involves more than one cycle of erosion, or a change from one process of erosion to another, find assistance in what may be called a three-fold manner of statement, which first sets forth the forms developed in the first cycle (or under the first process), then the movement by which the first cycle was interrupted and the second cycle introduced (or the change from first process to second process), and last describes the forms developed in the second cycle (or under the second process). In the first of these statements, the structure of the mass should be briefly stated, but the names of geological formations as well as all irrelevant geological matter, should be excluded or relegated to an appendix. The use of the present tense of verbs aids in turning attention from past processes to present products.

W. L. G. Joerg.
The Subdivision of North America into Natural Regions.—Printed in full herewith.

O. E. Baker (Introduced by C. F. Marbut).
A Proposed Atlas of American Agriculture.

Frank M. Chapman (Introduced by Ellsworth Huntington).
The Distribution of Life in Colombia.

Charles F. Brooks (Introduced by R. DeC. Ward).
The Snowfall about the Great Lakes.

The snowfall of the Great Lakes region is generally heavy. The north receives more than the south and the east shores much more than the west shores. For instance, Port Arthur, Ont. has a mean annual snowfall of 32 inches (since 1895), and White River, Ont. 93; Duluth, Minn. 49; Calumet, Mich. 136; Toronto, Ont. 56; Adams, N. Y. 171 inches. The extreme range of annual snowfall at White River (13 to 147 inches) is very great. This is nearly twice that at Calumet where the mean annual snowfall is much greater.

The west shores of the northern Lake region have more snowfall in December than in January and the maximum is in February. The west shores in the south have a pronounced maximum in February. On the other hand, the east shores of the north have their heaviest snowfall in December. The southern east shores have a January maximum.

The general conditions controlling snowfall are those of moisture and temperature. Here, snowfall is particularly favored by the large supply of water vapor from the Lakes and by the low winter temperatures. In the north, where practically all the winter precipitation is snow, a cold winter has relatively little snow because of the small moisture capacity of cold air and little evaporation from the frozen Lakes. But in the south, a cold winter has more snow than a warm one, for a smaller proportion of the precipitation is rain.

Actual precipitation under these favorable moisture and temperature conditions is brought about by numerous cyclones and by the effects of topography on winds. The general tendency toward the occurrence of heaviest snowfall in the north half of a cyclone is modified locally. In winter, moist winds blowing from a comparatively warm water-surface onto cold land precipitate snow through cooling by mixture and radiation and chiefly by forced ascent of the wind due to increased friction and to topography. Since this effect is greatest when the warm open Lakes are supplying abundant moisture, the maximum snowfall comes early in winter. The result is heavy snowfall on leeward or east shores (the prevailing winds are west and northwest). Snow drifting off ice on the Lakes onto the land is another, though small, source of leeward-shore snow.

The large variability of snowfall at a place like White River may be accounted for by the contrast between the heavy snowfall from occasional winds off the Lakes and the light snowfall from land winds. Thus the snowfall about the Great Lakes as elsewhere is inextricably under the control of moisture, temperature, wind and topography.

Roland M. Harper.

The Coniferous Forests of Eastern North America.

Most conifers tend to grow in pure stands, in some parts of their ranges at least, and therefore there are about as many types of coniferous forests as there are species of coniferous trees. They probably make up about three-fourths of our forests. The principal types in eastern North America are the jack pine, spruce, balsam, tamarack, and arbor vitae of the far north, the white pine and red pine in the vicinity of the Great Lakes, etc., the pitch pine of Long Island, New Jersey, etc., the red cedar of the interior hardwood region, the juniper or white cedar of the glaciated region and coastal plain, the two short-leaf pines of the South, the two cypresses of the coastal plain, the long-leaf pine of the coastal plain and southern mountains, and the Caribbean pine of Florida.

The distribution of each of these was described, and correlated with soil, temperature, precipitation, fire, and various other environmental factors. Some economic features of the different trees and of the regions in which they grow were also discussed.

Richard E. Dodge.
Geography Teaching in Normal Schools.

A study of the offerings in geography, as a part of the preparation of teachers for elementary schools, in 144 normal schools in the United States, including character of work, time allotted, methods of teaching employed, etc., with certain statements as to probable reasons for existing conditions.

C. J. Kullmer (Introduced by Ellsworth Huntington).
Storm Frequency in the United States and Europe.

The distribution of frequency of cyclonic areas in the United States has thus far been shown in two comparable series of ten year means for months and year, those of Dunwoody for 1878-87 and my own for 1899-1908. In order to study the shift of the storm track indicated by the comparison of the two series, a more extended and detailed study has been made, two fundamental changes in method being adopted: (1) the 5 degree unit areas of the former series were broken into two areas of 5 degrees longitude by 2½ degrees latitude, (2) instead of the former ten year means, yearly maps of storm frequency were made covering the complete material, 1874-1912. A mean yearly map based on 29 years was constructed, and the yearly departures from this mean obtained. A shift in latitude, uniform and distinct in three sun spot periods, is shown by comparison of years of solar maximum with those of solar minimum. Some individual years show striking departure from the mean. A shorter series of yearly maps was made for Europe, based on the complete material of monthly summaries of tracks as published by the Seewarte for the years 1876-1891.

Henryk Arctowski.
The Pleionian Variations of Temperature: the Brachypleions of Arequipa: Macropleionian Variations in the United States.

Ellsworth Huntington.

Climate and Human Efficiency.

One of the most important problems of climatology is to determine whether it is possible to obtain exact mathematical measurements of the effect of climate. This cannot be done by direct comparison between people in different parts of the world. The only feasible method seems to be to measure the efficiency of groups of people who remain under an otherwise uniform environment but are subjected to the changes of climate characteristic of our varying seasons. For this purpose the writer has obtained the records of 270 operatives who were doing piece work in factories in southern Connecticut. The record of each person extends over a year, and the 270 people cover the years 1910, 1911, and 1912. By averaging the wages earned each day it has been possible to construct curves showing the fluctuation of wages according to the season, according to the mean temperature, according to changes in temperature, and according to other climatic elements. The results show that barometric variations are less important than the writer supposed when communicating the preliminary results of the present investigation. Temperature, on the other hand, is far more important. The curves show that the climatic conditions of Connecticut cause a variation of at least 15% in efficiency. They further indicate that man is subject to the same biological laws as plants and animals, and that the effect of varying climatic conditions is probably closely connected with the amount of oxygen assimilated.

The method used in the present investigation opens a wide field for further study. By means of it we shall eventually be able to make a map of the world showing the numerical relationship between human efficiency and climate in any region where climatic records are available.

Hamilton Rice (Introduced by W. M. Davis).

Explorations in the Northwestern Part of the Amazon Valley.—Read by Title.

R. H. Whitbeck.

Some Economic Aspects of Glaciation in Wisconsin.—Printed in Annals, Volume III, pp. 62-87.

Frank Carney.

A Study of the Programs of this Association, 1904-1912.

Classification of the titles, abstracts, or published papers, presented in the annual programs of the Association of American Geographers during the past nine years, aiming to show the variety of interests exhibited by American geographers.

INDEX

Page
Amazon Valley, Explorations in the Northwestern Part of the, Hamilton Rice 145
American Agriculture, A Proposed Atlas of, O. E. Baker 142
American Cities, The Growth of, Mark Jefferson 141
American Climates, The Weather Element in, Robert DeC. Ward 3
Andrews, R. C., Explorations in Northern Korea 137
Anthropography of Guatemala, The, Ellsworth Huntington 139
Arctowski, Henryk, The Pleionian Variations of Temperature: the Brachypleions of Arequipa: Macropleionian Variations in the United States 144
Atlantic Ocean as an Inland Sea, The, Austin H. Clark 139

Baker, O. E., A Proposed Atlas of American Agriculture 142
Bowman, Isaiah, The First Decade 140
    Results of Expedition to the Central Andes 140
Brooks, Charles F., Snowfall about the Great Lakes 142
Brown, R. M., The Effects of Levees on the Height of River Beds 139
Bryant, Henry G., Government Agencies and Geography in the United States 135

Carney, Frank, A Study of the Programs of this Association, 1904-1912 145
Central Andes, Results of Expedition to the, Isaiah Bowman 140
Chapman, Frank M., The Distribution of Life in Colombia 142
Clark, Austin H., The Atlantic Ocean as an Inland Sea 139
Climate and Human Efficiency, Ellsworth Huntington 145
Colombia, The Distribution of Life in, Frank M. Chapman 142
Coniferous Forests of Eastern North America, The, Roland M. Harper 143

Davis, W. M., The Mission Range, Montana 135
    The Principles of Regional Exposition 141
Decade, The First, Isaiah Bowman 140
Definition and Boundaries of Physiographic Provinces in the United States, N. M. Fenneman 140
Delimitation of Spheres of Foreign Interests in Asia Minor, Geographical Influences in the, Leon Dominian 137
Distribution of Earthquakes, The, William Libbey 136
Distribution of Life in Colombia, The, Frank M. Chapman 142
Dodge, Richard E., The Geography of Power in Manufacturing in the United States 137
    Geography Teaching in Normal Schools 144
Dominian, Leon, Geographical Influences in the Delimitation of Spheres of Foreign Interests in Asia Minor 137

Earthquakes, The Distribution of, William Libbey 136
Eastern North America, The Coniferous Forests of, Roland M. Harper 143
Explorations in Northern Korea, R. C. Andrews 137
Explorations in the Northwestern Part of the Amazon Valley, Hamilton Rice 145

Fassig, Oliver L., The Frostless Period in Maryland and Delaware 137
Fenneman, N. M., Definition and Boundaries of Physiographic Provinces in the United States 140
    Physiographic Boundaries within the United States 84

Page
First Decade, The, Isaiah Bowman.......... 140
Frostless Period in Maryland and Delaware, The, Oliver L. Fassig.......... 137

Geographical Influences in the Delimitation of Spheres of Foreign Interests in Asia Minor, Leon Dominian.......... 137
Geographical Periodicals, A Subject Catalogue of, William Libbey.......... 136
Geographical Study of Nova Scotia, A, R. H. Whitbeck.......... 135
Geography of Power in Manufacturing in the United States, The, Richard E. Dodge.......... 137
Geography Teaching in Normal Schools, Richard E. Dodge.......... 144
Glacial Erosion from the Yosemite Region, Lessons in, F. E. Matthes.......... 138
Glacial Features of the Selkirks, Howard Palmer.......... 137
Glaciation in Wisconsin, Some Economic Aspects of, R. H. Whitbeck.......... 145
Glaciers and International Boundaries, Lawrence Martin.......... 138
Government Agencies and Geography in the United States, Henry G. Bryant 135
Great Lakes, The Snowfall about the, Charles F. Brooks.......... 142
Growth of American Cities, The, Mark Jefferson.......... 141
Guatemala, The Anthropography of, Ellsworth Huntington.......... 139

HARPER, ROLAND M., The Coniferous Forests of Eastern North America.......... 143
Human Efficiency, Climate and, Ellsworth Huntington.......... 145
HUNTINGTON, ELLSWORTH, The Anthropography of Guatemala.......... 139
    Climate and Human Efficiency.......... 145

Inland Sea, The Atlantic Ocean as an, Austin H. Clark.......... 139
International Boundaries, Glaciers and, Lawrence Martin.......... 138

JEFFERSON, MARK, The Growth of American Cities.......... 141
JOERG, WOLFGANG L. G., The Subdivision of North America into Natural Regions: A Preliminary Inquiry.......... 55

KULLMER, C. J., Storm Frequency in the United States and Europe.......... 144

Lessons in Glacial Erosion from the Yosemite Region, F. E. Matthes.......... 138
LIBBEY, WILLIAM, The Distribution of Earthquakes.......... 136
    A Subject Catalogue of Geographical Periodicals.......... 136

Manufacturing in the United States, The Geography of Power in, Richard E. Dodge.......... 137
MARTIN, LAWRENCE, Glaciers and International Boundaries.......... 138
Maryland and Delaware, The Frostless Period in, Oliver L. Fassig.......... 137
MATTHES, F. E., Lessons in Glacial Erosion from the Yosemite Region.......... 138
Mission Range, Montana, The, W. M. Davis.......... 135
Montana, The Mission Range, W. M. Davis.......... 135
Mouths of the Mississippi, New Land and Water Areas near the, E. W. Shaw 141

Natural Regions, The Subdivision of North America into, Wolfgang L. G. Joerg.......... 55
New Land and Water Areas near the Mouth of the Mississippi, E. W. Shaw. 141
Normal Schools, Geography Teaching in, Richard E. Dodge.......... 144
Northern Korea, Explorations in, R. C. Andrews.......... 137
Nova Scotia, A Geographical Study of, R. H. Whitbeck.......... 135

Page

Palmer, Howard, Glacial Features of the Selkirks........................ 137
Papers, Titles and Abstracts of.. 135
Physiographic Boundaries within the United States, N. M. Fenneman..... 84
Physiographic Provinces in the United States, Definition and Boundaries of, N. M. Fenneman.. 140
Pleionian Variations of Temperature: the Brachypleions of Arequipa: Macropleionian Variations in the United States, Henryk Arctowski. 144
Principles of Regional Exposition, The, W. M. Davis..................... 141
Programs of this Association, A Study of the, Frank Carney.............. 145
Proposed Atlas of American Agriculture, A, O. E. Baker.................. 142

Regional Exposition, The Principles of, W. M. Davis..................... 141
Results of Expedition to the Central Andes, Isaiah Bowman.............. 140
Rice, Hamilton, Explorations in the Northwestern Part of the Amazon Valley.. 145
River Beds, The Effects of Levees on the Height of, R. M. Brown.......... 139

Selkirks, Glacial Features of the, Howard Palmer....................... 137
Shaw, E. W., New Land and Water Areas near the Mouth of the Mississippi. 141
Smith, J. Russell, The Tree as a Factor in Man's Adjustment to the Arid Environment... 136
Snowfall about the Great Lakes, The, Charles F. Brooks.................. 142
Some Economic Aspects of Glaciation in Wisconsin, R. H. Whitbeck....... 145
Storm Frequency in the United States and Europe, C. J. Kullmer......... 143
Study of the Programs of this Association, 1904-1912, A, Frank Carney.... 145
Subdivision of North America into Natural Regions, The, Wolfgang L. G. Joerg.. 55
Subject Catalogue of Geographical Periodicals, A, William Libbey......... 136

Temperature, Pleionian Variations of, The: the Brachypleions of Arequipa: Macropleionian Variations in the United States, Henryk Arctowski. 144
Titles and Abstracts of Papers.. 135
Tree as a Factor in Man's Adjustment to the Arid Environment, The, J. Russell Smith... 136

United States and Europe, Storm Frequency in the, C. J. Kullmer........ 143
United States, Government Agencies and Geography in the, Henry G. Bryant 135
United States, Definition and Boundaries of Physiographic Provinces in the, N. M. Fenneman.. 140
United States, Physiographic Boundaries within the, N. M. Fenneman.... 84

Ward, Robert DeC., The Weather Element in American Climates......... 3
Weather Element in American Climates, The, Robert DeC. Ward.......... 3
Whitbeck, R. H., A Geographical Study of Nova Scotia................... 135
    Some Economic Aspects of Glaciation in Wisconsin................ 145

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